Conceptual Modelling of Drone Transport

Scenarios for the Future

Department Of Transport
and Main Roads

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Conceptual Modelling of Drone Transport Scenarios for the future

Department of Transport and Main Roads

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STRATEGIC CONTEXT

The use of drones to transport goods and people is emerging as an opportunity to help address transport challenges with innovative aerial transport solutions. Queensland already has a drone delivery service with Alphabet's Wing starting deliveries in Logan, Queensland in September 2019.

The *Queensland Transport Strategy (2020)* identifies the value of using emerging technologies, including drones, to transform the state’s transport system and meet customer’s and the economy’s changing needs.

The *Queensland Drone Strategy* (2018) sets the framework to capitalise on the state’s competitive advantages in drone technology. One of its actions is for the Department of Transport and Main Roads (TMR) to monitor and evaluate other jurisdictions' use and testing of new drone applications and technology.

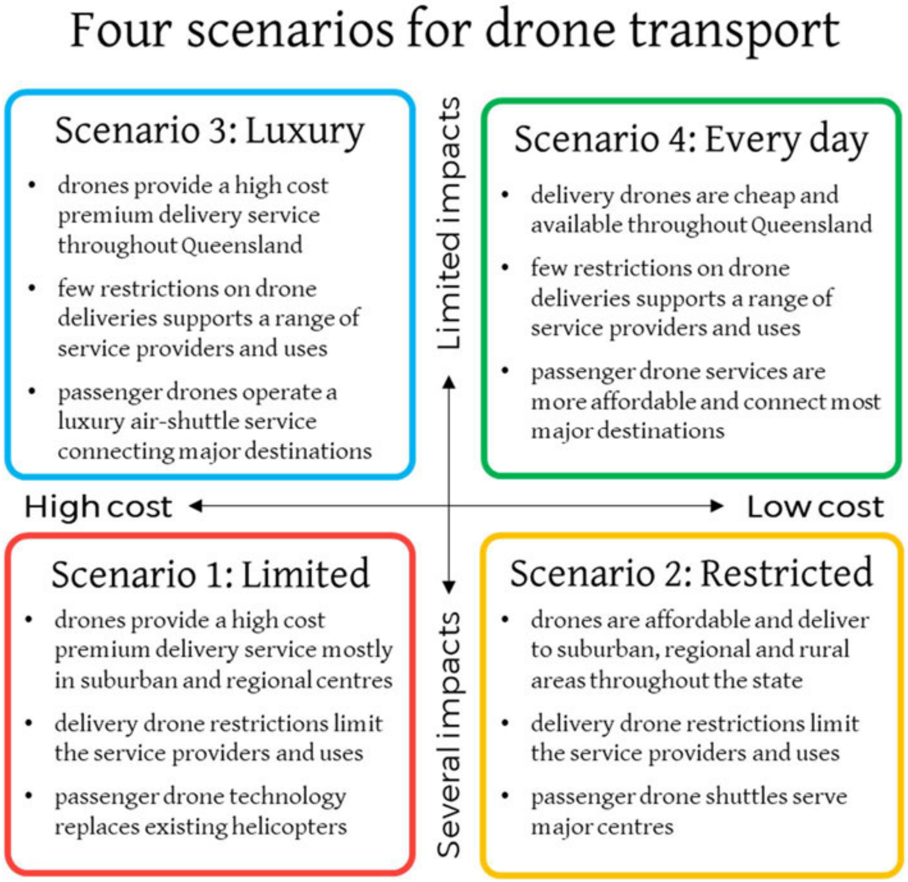
This report, collectively driven by the *Queensland Drones Strategy* and the *Queensland Transport Strategy*, sought to understand the opportunity delivery drones and passenger drones could present for the transport network. It also examines the challenges of this emerging technology and identifies suitable responses to these.

FOUR PLAUSIBLE FUTURES

Four plausible future scenarios were developed to assist in understanding the uncertainties around emerging transport trends. A conceptual model was then developed for drone transport services in South East Queensland (SEQ) to understand the implications of drones for the transport system under each of these four scenarios. While the modelling was limited to SEQ (primarily due to data availability), policy findings presented do consider regional implications.

The model cannot accurately predict the future as multiple factors will affect how drones and other disruptive technologies change our transport system. Instead the four scenarios seek to provide policy insight into the future opportunities and challenges presented by passenger and delivery drones. It is important to read the findings presented in this report in this context.

The scenarios varied the extent to which the technology could adequately limit negative impacts (the vertical axis), and how cost competitive the technology is compared to other transport options. The four scenarios are summarised in the figure below.



Four scenarios for drone transport

Scenario 3: Luxury
- drones provide a high cost premium delivery service throughout Queensland
- few restrictions on drone deliveries supports a range of service providers and uses
- passenger drones operate a luxury air-shuttle service connecting major destinations

Scenario 4: Every day
- delivery drones are cheap and available throughout Queensland
- few restrictions on drone deliveries supports a range of service providers and uses
- passenger drone services are more affordable and connect most major destinations

Scenario 1: Limited
- drones provide a high cost premium delivery service mostly in suburban and regional centres
- delivery drone restrictions limit the service providers and uses
- passenger drone technology replaces existing helicopters

Scenario 2: Restricted
- drones are affordable and deliver to suburban, regional and rural areas throughout the state
- delivery drone restrictions limit the service providers and uses
- passenger drone shuttles serve major centres

TEN PLAUSIBLE USES

The conceptual model of drone transport considered ten use cases identified through a review of current developments in the industry and international trends.

Goods Transport

Seven plausible situations were identified in which delivery drones could provide a service to the community and business that replaces existing small freight transport services. These did not include emergency response or monitoring functions for drones, although it is recognised that these could be important roles for drone technology. These use cases identified are:

- Local courier services
- Local food takeaway delivery
- Shopping centre delivery to customers
- Direct distribution from warehouse to customer
- Internal business supply-chain logistics
- Supply-chain logistics between businesses
- Health industry service between hospitals and clinics.

Passenger Transport

Three passenger use cases were modelled to understand the potential role for drones in the passenger transport system. These use cases are:

- Air Metro
- Air Taxi
- Private ownership of drone transport.

The conceptual model used existing data, population projections and travel behaviours to estimate passenger and delivery drones demand in the four future scenarios.

Likely locations for drone vertiports and delivery hubs were based on existing and planned land uses. The model assumes drones travel on direct routes, without current airspace restrictions, which would severely restrict drone flight paths in much of the urban areas of SEQ.

KEY RESULTS

The scenario modelling shows that drone transport will likely have limited ability to reduce traffic congestion in SEQ. Drone transport does however deliver value by making it possible to bypass traffic congestion for trips with a high time value. Drone transport service can also benefit island communities and outer suburban areas with high levels of car dependence.

DELIVERY DRONES

Future SEQ demand

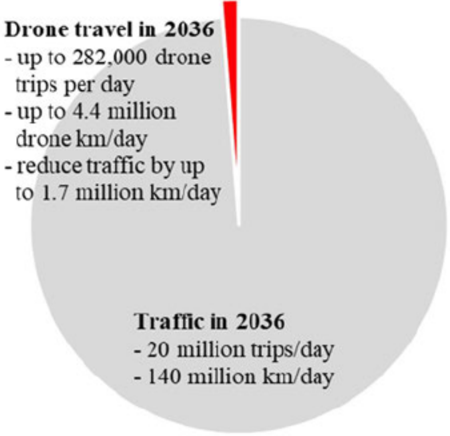
- 108,000 to 278,000 trips/day
- 1.6 to 4.4 million km/day

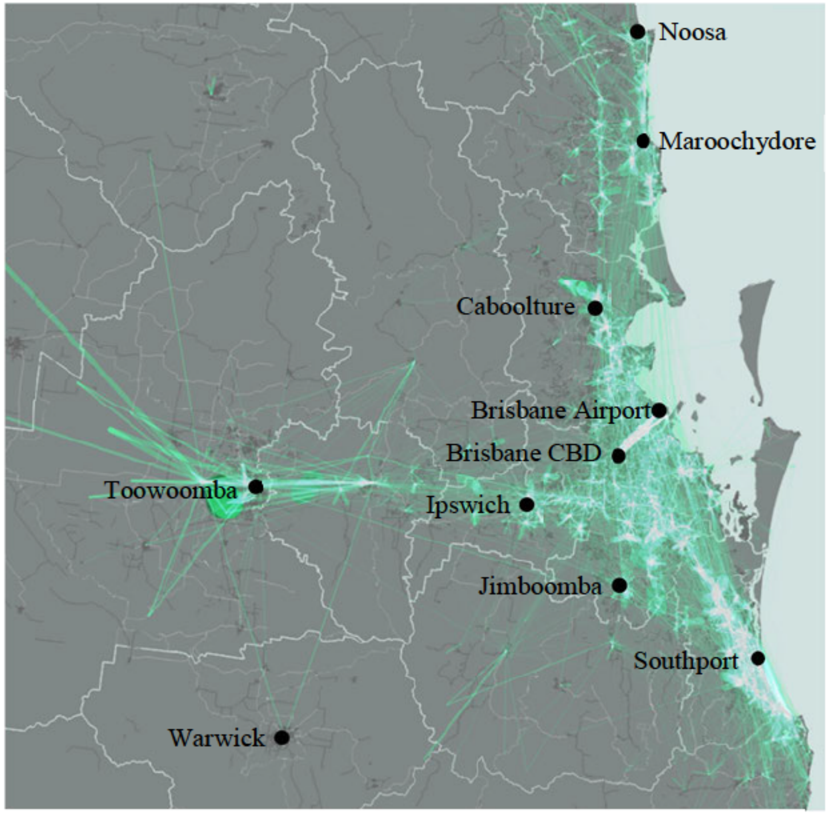
PASSENGER DRONES

Future SEQ demand

- 1,000 to 4,000 trips/day
- 23 to 30 thousand km/day

SEQ CONGESTION BENEFIT





Scenario 4: Distribution of daily drone trips in SEQ

FINDINGS AND NEXT STEPS

1 Drones could help address transport disadvantage in outer suburban, rural and island communities

Low-density outer suburban areas, island communities and rural properties have high levels of car dependence, long distances to travel or difficulty in making trips. Delivery drones could improve the ease and reduce the cost for customers in these communities to buy goods and food. The isolation from commercial centres and the low density of demand provide a distinct competitive advantage for drones over other modes of transport.

Drone delivery service could reduce the need for private mobility in transport disadvantaged locations by providing a viable transport alternative. Delivery drones also have great potential to support positive health outcomes in remote communities by reducing the cost and delay to transport test samples, equipment and medication.

Suggested response: investigate opportunities to facilitate drone delivery services and health-related drone services for transport disadvantaged and regional communities.

2 Drone transport services are not likely to relieve congestion on QLD's land transport network

Delivery drones and passenger drones are only expected to reduce daily vehicle kilometres travelled in SEQ by up to 1.2%. As most drone trips made are expected to serve suburban areas, the reduced vehicle travel will therefore primarily not be on congested corridors.

Although passenger drones will provide a high travel time benefit to users of congested corridors, their high cost and limited landing locations would restrict the potential for any significant congestion benefit.

Suggested response: the case for drone transport is unlikely to be built on the congestion reduction benefits. Support for drone transport initiatives should be built on other benefits realised by drones.

3 Existing aviation regulation and infrastructure could limit the scale of drone transport services

Existing Federal aviation regulation and governance structures focus on long-distance aviation activities and are not equipped for highly-localised urban drone transport. The regulation of airspace, including the current drone no-fly zones, and the current aviation infrastructure is not configured for a large increase in urban aviation that could arise from delivery and passenger drones.

Currently State and Local Governments do not have regulatory responsibility for most aviation activities. Drone transport innovations are facilitating disruptive change in the field of aviation, and all tiers of government need to contribute to revisiting existing regulations and infrastructure to support positive outcomes for the community from drone transport service.

Suggested response: State and Local Government in Queensland needs to engage with Federal regulators of aviation to appropriately position the state to maximise the potential for drones in Queensland.

4 Noise and environmental impacts of drone transport technology is poorly understood

Recent trials of drone deliveries in Canberra have highlighted community concerns about the noise, privacy and the environmental impact of drones. However, current trials in Logan have not yet resulted in a similar level of community concern. The impacts of transport drones on communities and the environment is not yet well understood as there is no long-term research on this new application for drone technology.

There is a need for research into the impacts of transport drones and the appropriate controls required to minimise negative impacts while realising the benefits of drone transport to Queensland communities.

Suggested response: the Logan trial of delivery drones presents an opportunity for Queensland research into the impact of transport drones on the community and the environment.

5 There are no land use planning instruments appropriate for regulating the use of land for delivery drone hubs or passenger vertiports

The location of drone hubs and vertiports will have a major influence on the potential for delivery and passenger drones to provide a viable service to communities. However, drone hubs and vertiports will generate noise impacts on surrounding land uses, depending on the level of use of the facility.

There are currently no land use planning instruments available for local government to regulate the use of land as a drone delivery hub or vertiport. There is a need for a classification system for drone noise to inform the development of appropriate land use policy for drone delivery hubs and vertiports.

Suggested response: State and Local Government should collaborate to develop suitable planning instruments for Local Government use in regulating the development of land as drone hubs or vertiports.

CONCLUSION

The use of drones to transport goods and people presents opportunities to innovate in addressing transport challenges throughout Queensland. The findings of this investigation are not intended as an accurate prediction of the future for transport drones. Instead they provide a common starting point for conversations within government, with business, and with the community. These conversations will help shape policy on state and local government roles in planning, regulating and facilitating the use of drone technology to address Queensland’s transport challenges.

1 INTRODUCTION

1.1 PURPOSE

This report examines the opportunities, constraints and risks related to the use of drones for transport purposes. The aim is to identify the policy and strategy implications for Queensland and to provide a framework for discussing the role drones could play in Queensland's future transport system.

The conceptual modelling of drone transport does not provide an accurate prediction of the future. Instead it provides a common starting point for conversations within government, business, and the community. These conversations will help shape policy on state and local government's roles in planning, regulating and facilitating the use of drone technology to help address Queensland's transport challenges.

The key project objectives are to:

- Identify the potential transport functions that drone technology could support
- Develop future scenarios to test alterative futures for drone transport
- Undertake conceptual modelling of future drone transport demand in South East Queensland (SEQ)
- Assess the potential scale of the drone transport task, and its potential to reduce traffic congestion
- Make recommendations for government on drone transport's policy and strategy implications.

1.2 BACKGROUND

The *Draft Queensland Transport Strategy* (TMR, 2019) sets out a 30-year vision of flexibility to harness emerging technologies and services to transform the state's transport system and meet customers' and the economy's changing needs. Drones can potentially contribute to Queensland's transformation to a safer, greener and more efficient future.

Queensland is well positioned to become a world-leader in the rapidly growing drone industry. The *Queensland Drones Strategy* (Queensland Government, 2018) sets the framework to capitalise on the state's competitive advantages to support strong investment and jobs growth in drone technology and its application in the state.

The Department of Transport and Main Roads (TMR) is responsible for the following actions emanating from the Strategy:

- Monitor and evaluate other jurisdictions' use and testing of new drone applications and technology
- Develop an internal Queensland Government Drones Use Policy that provides information to all agencies on the use of drones
- Develop policy regarding government and non-government drone use in state-controlled transport corridors and maritime jurisdictions

1.3 RELEVANT TRENDS

The idea of drones providing transport services is not new. At the 1900 World Fair in Paris, it was predicted that by the year 2000 we would be navigating our cities using flying machines, and rural postmen would deliver the mail using air scooters (Dunn, 2018).

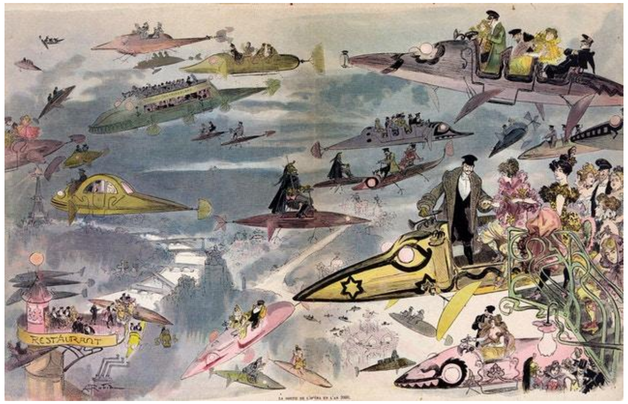


Figure 1.1 Flying carriages in the year 2000

Although a little early, the predictions are not too far from reality due to changes in our communities and disruptive developments in technology. Some key trends in society, technology and the economy now present opportunities for drones to serve a transport role.

These opportunities could deliver alternative future outcomes for the transport system, depending on how government, industry and the community respond.

SUSTAINED URBAN GROWTH

Queensland’s population is projected to almost double by 2066 (QLD Treasury, 2018). Most of the projected population growth is in South East Queensland (SEQ) with resident numbers growing from 3.5 million to 5.3 million over the next 25 years (DILGP, 2017).

Increasing urban traffic congestion from this growth needs to be managed to deliver sustainable economic, social and environmental outcomes. Growth can also worsen spatial inequalities faced by outer-urban communities due to poor access to services and high levels of car-dependence.

Emerging technologies, including drones, have the potential to provide a transport service that reduces car dependence and helps address traffic congestion by bringing goods and services to customers.

THE ECONOMIC VALUE OF REGIONAL QLD

Primary production is important to the state’s economy with mining contributing almost 12% (QLD Treasury, 2019) and agriculture 4% (DAF, 2018) to the Queensland economy in 2018. Although Queensland’s population growth will mostly be urban, regional areas will continue to underpin the state’s economy. The transport challenges of regional and remote communities increase the costs of living and working there.

Drones have the potential to provide remote mines and farms with quick and cost-effective goods delivery. Drone delivery of items with a high time-value, such as spares critical to production, or urgent medical supplies for staff or livestock, could improve economic and health outcomes in these communities. Drones could also be used to provide easy access to consumer goods that otherwise would be difficult to get for people living in remote areas.

Autonomous passenger drones are predicted to be ten times less expensive to operate than helicopters (Porsche Consulting, 2018), making cost-effective regional air travel more viable. This could help address regional communities’ isolation by making air travel significantly less expensive.

GROWTH IN ONLINE RETAIL

In 2018, Australians spent $27.5 billion buying goods online – 10% of the total value of retail sales, up from 8% in 2017. Queensland leads online retail growth, which increased 22% from 2016 to 2017 (Australia Post, 2019).

Online retail is constrained by the time delay between purchasing products and receiving them. Australian customers want the convenience of quick delivery with next-day delivery services increasing by almost 32% in 2018 (Australia Post, 2019). Next-day delivery gives retailers a competitive edge, particularly in fashion-related retail and before major events like Christmas. But customers are highly price sensitive and 70% base their delivery choice primarily on price (McKinsey & Company, 2016).

Drones could disrupt the last-mile delivery industry by making same-day delivery feasible and reducing delivery costs for small packages. Cost efficiency improvements could grow same-day or instant parcel delivery to between 20% and 25% of the online retail market (Laseter, Tipping, & Duiven, 2018). This could support a rapid expansion of online shopping for small items where the convenience of instant drone delivery outweighs the cost.

DISRUPTIVE CHANGE IN TRANSPORT

As the world entered the 20th century, the bicycle and then the internal combustion engine transformed how people travelled and where they lived. Today, digital technology is disrupting the transport status quo, with potential to change the way we travel, and where we live and work. Major transport disruptors include:

- mobile applications streamlining access to taxi and ride-share services
- alternative fuel sources, including battery and fuel cell hydrogen technology
- shared mobility systems, including bicycle, scooter and car-sharing applications
- Mobility as a Service (MaaS) platforms including multiple mobility options in a subscription service
- autonomous (driverless) vehicle systems
- electric mobility devices including bicycles, scooters, skateboards making active transport easier
- unmanned aerial vehicles (drones).

The future outcomes of these disruptive changes will depend on the pace of technology developments, how the community responds, and where the public and private sectors invest. Drones have the potential to offer a unique product choice in the new transport ecosystem.

2 DRONE DEVELOPMENTS

2.1 ENABLING TECHNOLOGY

Technology for drone transport applications is progressing rapidly with multiple parties involved as regulators, customers and technology developers. There is strong competition within the market to lead the rollout of commercial freight and passenger drones.

Drone technology includes Remotely piloted aircraft systems (RPAS), unmanned aerial vehicles (UAV) and unmanned aerial systems (UAS). The term ‘drone’ was originally used to refer to UAVs in World War II. Until recently, drones were restricted to military use for surveillance and engagement.

Civilian and commercial drone use for data gathering, photography and other uses have grown rapidly as technology development has reduced costs and increased reliability and capability. The drone economy currently has an estimated global value of over $137 billion a year, with over 50,000 recreational and 1,000 commercial drone operators in Australia (Parliament of Australia, 2018).

The use of drones for transporting goods and people is being facilitated by advancements across multiple enabling technologies, including:

- communications technology
- GPS accuracy
- size, weight and cost of sensors
- small and energy efficient microprocessors
- battery energy density and cost
- artificial intelligence
- designs to reduce the noise levels of drones
- Unmanned aircraft system Traffic Management (UTM).

Technologies leading the advancement of drone transport applications are related to battery energy density and cost, and technology for managing the noise drones produce.

BATTERY TECHNOLOGY

Drones’ transport role is most influenced by battery energy density and cost. This determines their lift capacity, operating range and costs.

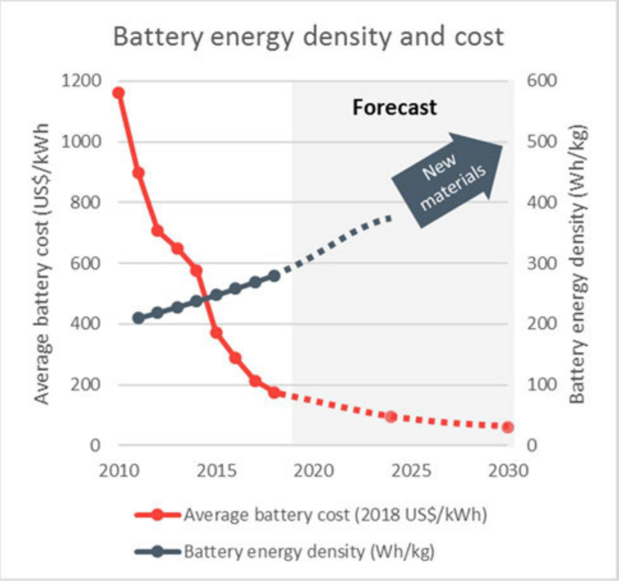
In the early 1990s, the introduction of lithium-ion battery technology generated rapid growth in the energy density of batteries. Since 2010, batteries’ energy density (Wh/kg) has increased at about 4% per year, and is now approaching the US Department of Energy’s 350 Wh/kg 2020 target (Green Car Congress, 2019).

Current international research focusses on batteries with a target energy density of 500 Wh/kg, a cost of US$100/kWh and a charging time of 15 minutes or less (US Department of Energy, 2018). Research shows that new materials for batteries will be needed to continue increasing their energy density. At the current development rate, by 2030 we may achieve 460 Wh/kg energy density (Bloomberg, 2019) such that drone technology could carry 30% heavier payloads or travel 30% further.

Advancements in drone propulsion systems, and improvements in battery array cooling systems are expected to increase this growth rate in drone flying distance and payload capacity.

Since 2010, the real cost per kilowatt hour (kWh) of lithium-ion batteries has reduced more than 20% per year (Goldie-Scot, 2019). This rapid reduction in costs cannot be sustained and by 2030 the average cost of batteries is expected to be US$62/kWh (Bloomberg, 2019).

The transport uses for drone technology will expand as battery energy density improves and batteries’ costs reduce.



Source: *Green Car Congress (2019), Bloomberg (2019)*

Figure 2.1 Battery energy density

NOISE MANAGEMENT TECHNOLOGY

There are currently no industry standards for measuring and reporting drone-generated noise. The Federal Department of Infrastructure, Transport, Cities and Regional Development (DITCRD) regulates aviation noise and is currently investigating the appropriate scope and breadth for Federal regulation of community noise impacts from drone operations.

Community perception of noise is influenced by how loud the noise is, its duration, the time it occurs, and the level of irritation it causes. Peoples' perception of irritation from drone noise as distinct from other noises is not well understood. The high pitch of drones is unlike most other noises, making it noticeable, and hence irritating.

Figure 2.2 illustrates the sustained noise levels typical in a range of different environments. The optimal level of noise in suburban areas is an average of 45 decibels (dB) over 15 minutes. The noise from a lawnmower is around 70 dB measured from a neighbour's property 15 meters away. Although it is louder than the desired average noise levels, people's familiarity with lawnmower noise makes it acceptable, despite being over 10 or more minutes.

Noise research in 2018 and 2019 for drone delivery trials in Canberra, measured the intensity, tone and duration of drone noise when under flight and during delivery. Drone deliveries generated their maximum noise level while hovering to make a delivery. A peak noise level of 69 dB was measured at a distance of 15 m (DITCRD, 2019), which is similar to the noise from a lawnmower. As the delivery duration is less than one minute, the noise impact from a drone delivery would be much less than from a neighbour mowing the lawn.

Noise levels of delivery drones in flight were measured at 55 dB from 25 m away. That would be quieter than the typical noise level in a busy office. The high speed of the drones in flight would also limit the duration of the noise to a few minutes.

Increasing the payload of drones to carry heavier loads is likely to increase noise intensity and could change its tone. Current research and development shows that passenger drones generate three times less noise than helicopters (Volocopter, 2019). The noise generated is expected to be less irritating than helicopters by using many smaller rotors on the passenger drone.

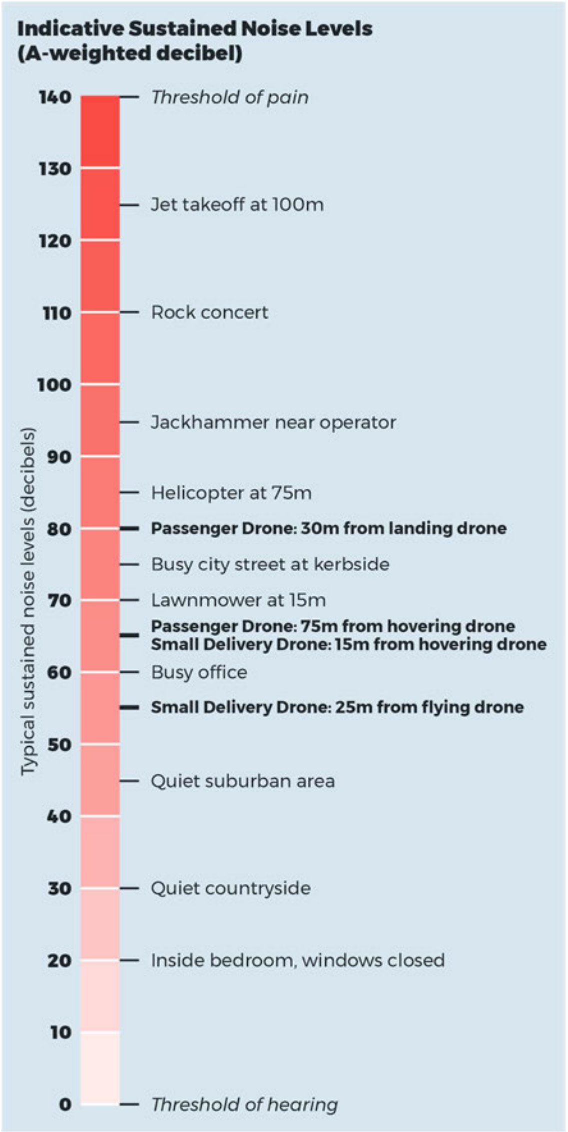
However, people's perception of noise would not just depend on the noise generated by one drone, but by the cumulative impact of many drones. People living close to locations where many drones fly past or hover, would be more affected by drone noise.

Future regulation to mitigate this potential noise impact is likely. The nature of the restrictions will depend greatly on how drone technology improves their noise levels.

Locations for basing delivery drones are called drone 'nests' or delivery hubs. Locations serving passenger drones are termed vertiports. The cumulative effect of multiple delivery or passenger drones accessing the drone delivery hub or the vertiport would most likely restrict their location to areas where their presence would only minimally change ambient noise levels, or where no residents live close enough to be affected.

The impact of drone noise on wildlife is not known as there has been very limited research. Like humans, wildlife in areas with low ambient noise will likely be more affected by drone-generated noise. The level of disturbance and the long-term impacts are not known and require further research (Mulero-Pazmany, 2017).

There is a need to better understand the impacts of drone noise on communities and the environment, and the potential for drone technology advances to reduce theses noise impacts.



Source: *Based on* QLD Noise Measurement Manual (DEHP, 2013)

Figure 2.2 Typical sustained noise levels

2.2 DRONE TRIALS

In August 2019, more than 40 locations were operating or planning trials for drone transport applications, as shown in Figure 2.3. Key metrics from some of the trials are included in Table 2.1 to illustrate existing drone technology's current range of capabilities.

Active drone trials are currently limited to parcel delivery, with widespread commercial operations expected by 2025 (McKinsey & Company, 2018). Canberra has one of the few drone trials internationally with deliveries directly to customers. Key trial findings are discussed in the following section.

Several trials test the transport of health-related items between remote communities and medical facilities in centres. These trials demonstrate the value of drones in improving vital health service to remote communities.

Passenger drone trials are limited to research, development and testing, with commercial operations expected after 2025 (McKinsey & Company, 2018). However, prototype passenger drones have demonstrated the ability to carry one passenger up to 40km distance at a speed of 100 km/h (EHang, 2019).

Table 2.1 Current drone capability

PROJECT	PAYLOAD (KG)	DISTANCE (KM)
Germany	11	0.7
North Carolina, USA	2.3	20
Ireland	2	5
Japan	5	16
Ethiopia	5	150
Australia	5	10
Canada	11	60
China	100	40

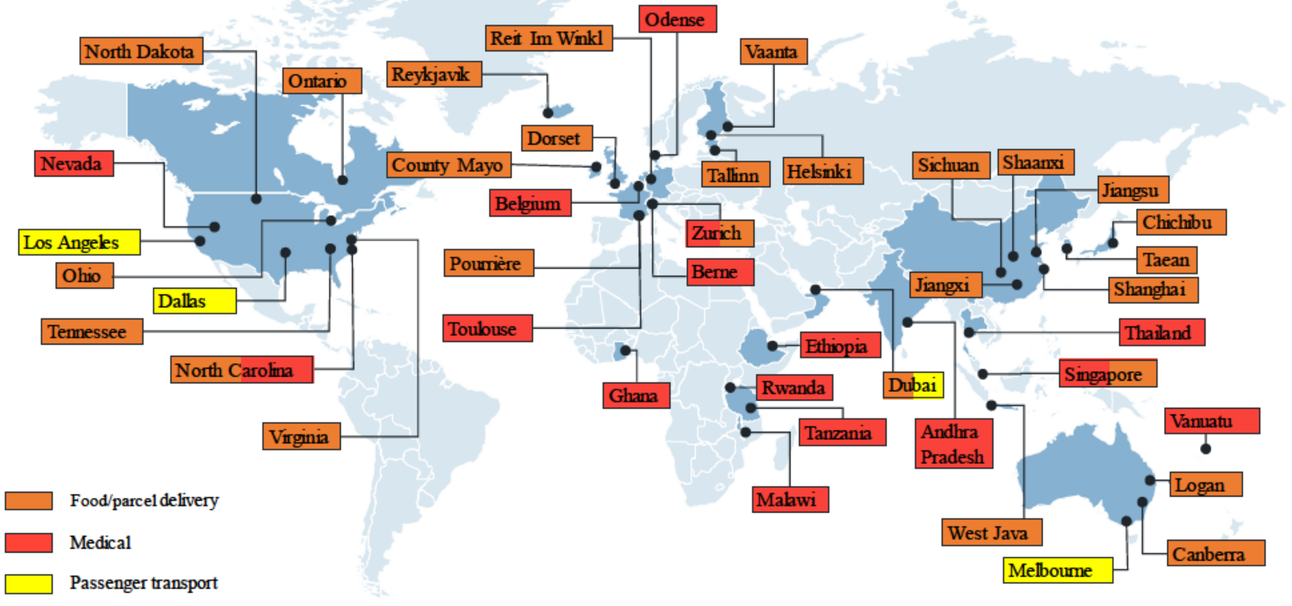


Figure 2.3 Location of current trials of transport uses of drones (Aug 2019)

Wing services in Australia

Since 2018, Wing, part of the Alphabet group, has operated a drone trial of food and other small item deliveries in Canberra. In July 2019, Wing announced Logan in QLD as its next drone delivery service location.

Wing's Canberra delivery facility is in an industrial estate in Mitchell. It includes the 'nest' where drones are recharged, and suppliers' areas where drones wait on 'perches' to collect orders.

The facility serves up to a 10 km radius that includes rural, suburban and inner-city areas. By mid-2019, more than 2,000 drone deliveries had been made to Canberra's rural and suburban customers. Once the trials have demonstrated delivery drones' safety, reliability and convenience, deliveries to inner-city areas will follow.

Some key learnings from the trials include:

- The main community concerns are noise, wildlife disturbance and privacy
- Fastest time from order to delivery = 2.43 minutes
- Users report an average 6-10 minutes' wait time
- Four-times more coffees are ordered than the next most popular item.

The Canberra trial's success has potentially laid the foundation for drone delivery services to start operating in other Australian cities. In June 2019, Amazon announced plans to start commercial drone deliveries when and where they have regulatory support (Amazon, 2019). In September 2019, the Civil Aviation Safety Authority (CASA) approved Wing to operate a drone delivery service in Logan, Queensland.

3 FACTORS AFFECTING DRONE TRANSPORT FUNCTION

There are several factors that affect drone technology’s potential transport function. These are briefly discussed to help lay the foundation for developing a concept model of drone demand.

3.1 AREAS SERVED

INNER-CITY AREAS

Inner-city areas are characterised by a high concentration of people and activities. This generates high potential demand that could deliver economies of scale, particularly for passenger drones connecting to major urban centres.

However, the higher development density increases the potential for conflicts between drones and elevates risks to the public if a crash or failure occurs. With more people around, landing passenger drones carry higher risks, and delivering items by drone to the correct person may involve challenges. To manage these risks, drone delivery hubs and passenger vertiports will likely be required in inner-city areas.

Land-based transport options may be more convenient and faster for shorter trips than drone transport, due to the time lost in accessing the drone delivery hub or vertiport. Figure 3.1 compares travel by passenger drone to travel by car. The benefit level of drone transport will depend on the time lost in accessing the service, and the time gained by avoiding traffic congestion.

These factors are expected to limit the inner-city market percentage that drones will serve. The large numbers of people and activities will still make it an important market for passenger drone transport, despite the smaller percentage of trips served.

Drones could transform supply-chain logistics by providing just-in-time-supply unaffected by traffic congestion. This will have particular benefits for time-critical deliveries, such as health services.

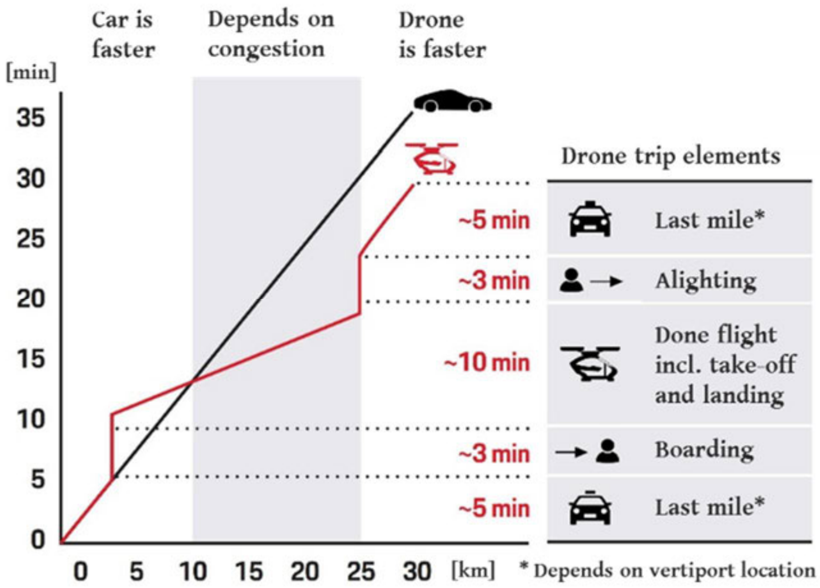
SUBURBAN AREAS

Suburban areas are characterised by lower development densities and higher levels of transport disadvantage, especially in outer-suburban areas. The lower development density makes it easier for drones to directly serve homes at a low public safety risk. Suburban residents have higher levels of dependence on private cars for access to shops, particularly in outer-urban areas. This will make drones very convenient and cost-competitive for instant and same-day delivery.

With less traffic congestion, suburban business may mostly benefit by using drones to improve supply chain efficiencies and improve ease of business-to-business trade between dispersed locations.

Noise is likely to be a constraining factor that could restrict numbers of drone trips and drone payloads to minimise community impacts. This could present challenges to commercial drone transport services.

Drones could benefit emergency services in the suburbs by rapidly delivering life-saving equipment or medication directly to patients.



Source: Porsche Consulting (2018)

Figure 3.1 Trip comparison of drone and car

REGIONAL AREAS

The high cost of driving to regional and remote areas isolates them and high transport costs increase the cost of goods and services. Drones can provide quick and cheap goods and passenger transport serving regional and remote areas, reducing isolation and the cost of goods.

The distances travelled would limit the size and weight of drone payloads, making autonomous vehicles more efficient in servicing remote communities. Drones would provide an advantage where quick delivery is highly valued, or where road access is difficult.

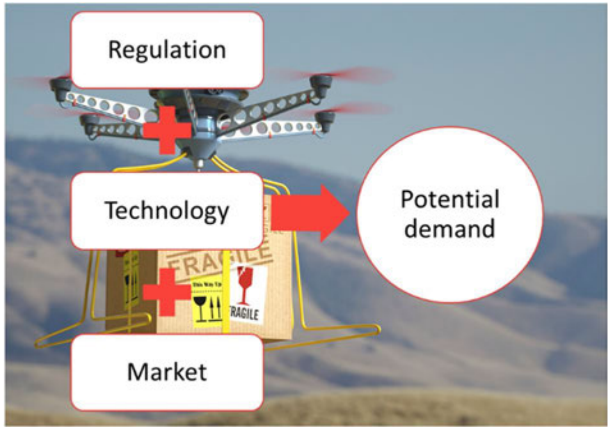
Due to their speed, drones would best be suited for health-related services or to deliver urgent goods or spares to regional and remote communities and businesses. Passenger drones with their lower costs also have the potential to replace helicopters serving regional and remote communities.

3.2 DEMAND DRIVERS

The demand for drone transport affected by three key interrelated factors:

- **Regulation**: Federal, state or local government regulations and policies related to safety, amenity, privacy and the environment.
- **Technology**: How technology facilitates or constrains potential due to vehicle, system and external factors.
- **Market**: The competing modes that influence potential demand for drone transport.

The interrelation of these regulatory, technological and market factors will influence potential demand. The following sections briefly outline how these may influence the potential demand for drone transport.



REGULATORY FACTORS

Government regulation aims to manage drone activity's negative impacts on the community, environment or the economy. Using drones to transport goods and people is rapidly becoming a reality and government regulations (internationally) are evolving to keep pace.

Current legislation and policies are written for either manned aircraft or legacy remote-piloted model aircraft. Their main objective is to:

- ensure public safety
- manage noise impacts on communities.

Existing legislation does not adequately apply to drones, but is changing as drone trials progress and government better understands the risks, issues and impacts.

The roles of state and local governments in regulating and managing impacts from drone transport are currently not well understood or defined in Australia or internationally.

Queensland is a notable Australian exception as it has enacted legislation specific to regulating drone flight above state transport corridors.

Globally, states and cities have identified a need for policy and regulatory frameworks to create an environment that supports transport drones' potential benefits, while mitigating their negative impacts.

Drone no-fly zones are currently defined for public safety, security and environmental reasons. Some communities have called for new or expanded drone no-fly zones to address concerns about noise, environmental impacts, and privacy. Restricting drone use of airspace could have major impacts on the costs and scale of drone transport.

TECHNOLOGY FACTORS

Drone technology is rapidly developing and this will influence the potential drone transport demand by:

- minimising the regulatory constraints by managing risks to public safety and minimising noise impacts
- efficiently managing low-level airspace
- increasing drones' payload capacity and range
- minimising weather disruptions to drone services
- reducing the costs of drone transport.

Over time, technology developments will change the extent to which these factors influence demand.

MARKET FACTORS

The demand for transport drones will be influenced by how the service competes with other existing and emerging transport technologies. Demand for drone transport services will be greatest where other transport options cannot provide a cost-competitive service.

A lack of infrastructure supporting drone transport services requires service providers to invest. Services needing minimal infrastructure (like delivery drones) can be cost effective, while those needing major infrastructure (such as passenger drones) would require more capital investment, increasing costs and limiting the demand.

3.3 DRONE PAYLOAD AND RANGE

The transport function that drones can play depends on the payloads drones can feasibly carry and the distances they can fly (their range).

Safety restrictions are likely to limit where drones with heavier payloads can land. For the modelling of demand, it was assumed that restrictions would vary as follows:

- small drones (less than 5 kg payload) have few restrictions preventing door-to-door delivery, except where development density is high
- medium drones (5 kg to 50 kg payload) have some restrictions that make door-to-door service less viable, except in areas of low development density
- large drones (more than 50 kg payload) have restrictions limiting their landing areas to vertiports.

Small delivery drones are likely to be less competitive than land-based modes for short-distance deliveries (less than one kilometre) (AlphaBeta, 2018).

For medium delivery drones the demand modelling analysis assumed the restrictions would make land-based modes more cost-competitive for trips less than 3 km.

Large delivery drones and passenger drones are likely to take longer than ground transport for shorter trips due to the need to use vertiports. International research indicates that passenger drones would probably be faster than ground-based transport for trips over 20 km (Porsche Consulting, 2018), but this would depend on how easy it is to access vertiports, and the time advantage drones offer over land-based modes.

The drone modelling analysis has assumed a 10 km minimum distance for large drone trips to test a future with high traffic congestion levels and relatively easy access to vertiports.

The drone transport demand analysis assumed that people are unlikely to make drone transport trips for distances shorter than those illustrated in Figure 3.2 for the different drone types.

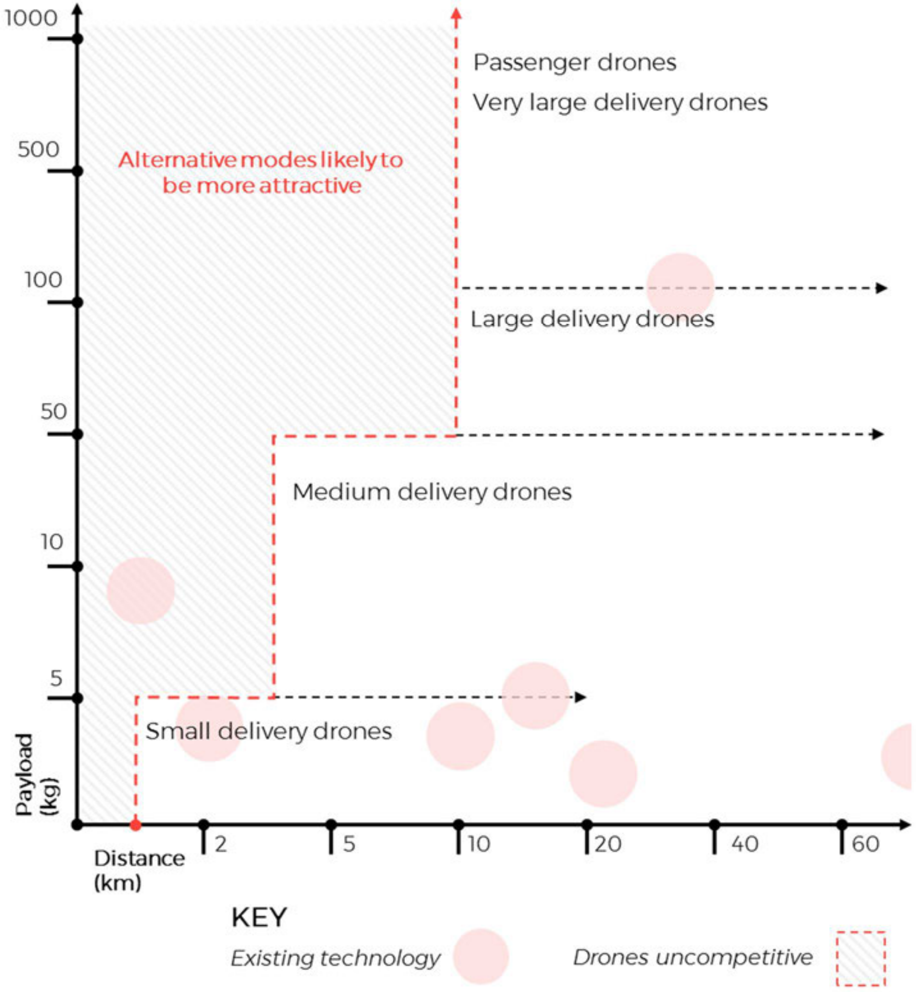


Figure 3.2 Drone payload and distance ranges

3.4 TRANSPORT FUNCTIONS FOR DRONES

The future transport functions for drones will depend on several factors including drone technology, regulatory constraints, and market viability.

Internationally there are trends emerging in drone transport functions. Ten functions (described) were identified where potential demand scenarios could be modelled in South East Queensland.

The following were not modelled as they are more random or have peripheral transport functions.

- rapid response drones transporting life-saving medication or equipment to the site of an emergency
- road traffic law enforcement drones
- transport infrastructure monitoring drones.

Source: Volocopter (2019)

GOODS TRANSPORT

1. **Local courier service**: small to medium drones provide courier services for express-mail or parcel delivery between customers.
2. **Local takeaways**: small delivery drones provide a lower-cost delivery service, replacing vehicle deliveries or customers fetching takeaways.
3. **Shopping centre distribution:** shopping centres supplement their business though on-line shopping and same-day delivery service to customers using small and medium delivery drones. This replaces people visiting shops.
4. **Direct distribution:** online retailers provide same-day goods delivery from centralised warehouses direct to customers. Small, medium and large drones replace courier or postal delivery.
5. **Internal supply-chain logistics**: businesses optimise their internal supply-chain logistics between facilities by using medium to large drones instead of vehicles.
6. **External supply-chain logistics**: medium to large drones improve business efficiency through rapid delivery of urgent supplies, or small tools from suppliers directly to job sites.
7. **Health industry service**: small, medium and large delivery drones transport urgent blood tests, medication, or equipment between hospitals, clinics, laboratories and doctors' surgeries.

PASSENGER TRANSPORT

8. **Air metro**: a low-capacity public transport service providing scheduled routes between major destinations where distance or traffic congestion gives air travel an advantage over land transport.
9. **Air taxi**: air-taxis would provide an on-demand service between vertiports located where demand justifies the infrastructure investment. Urban drones would likely be unable to provide 'door-to-door' service in urban areas and would need to use vertiports. The service would benefit from being part of an integrated multi-modal Mobility as a Service (MaaS) offering.
10. **Private drone transport**: like private helicopter ownership, private drone owners would be very wealthy, and/or would require the drone for work purposes – such as farmers. In urban areas, the services will likely need to use vertiports.

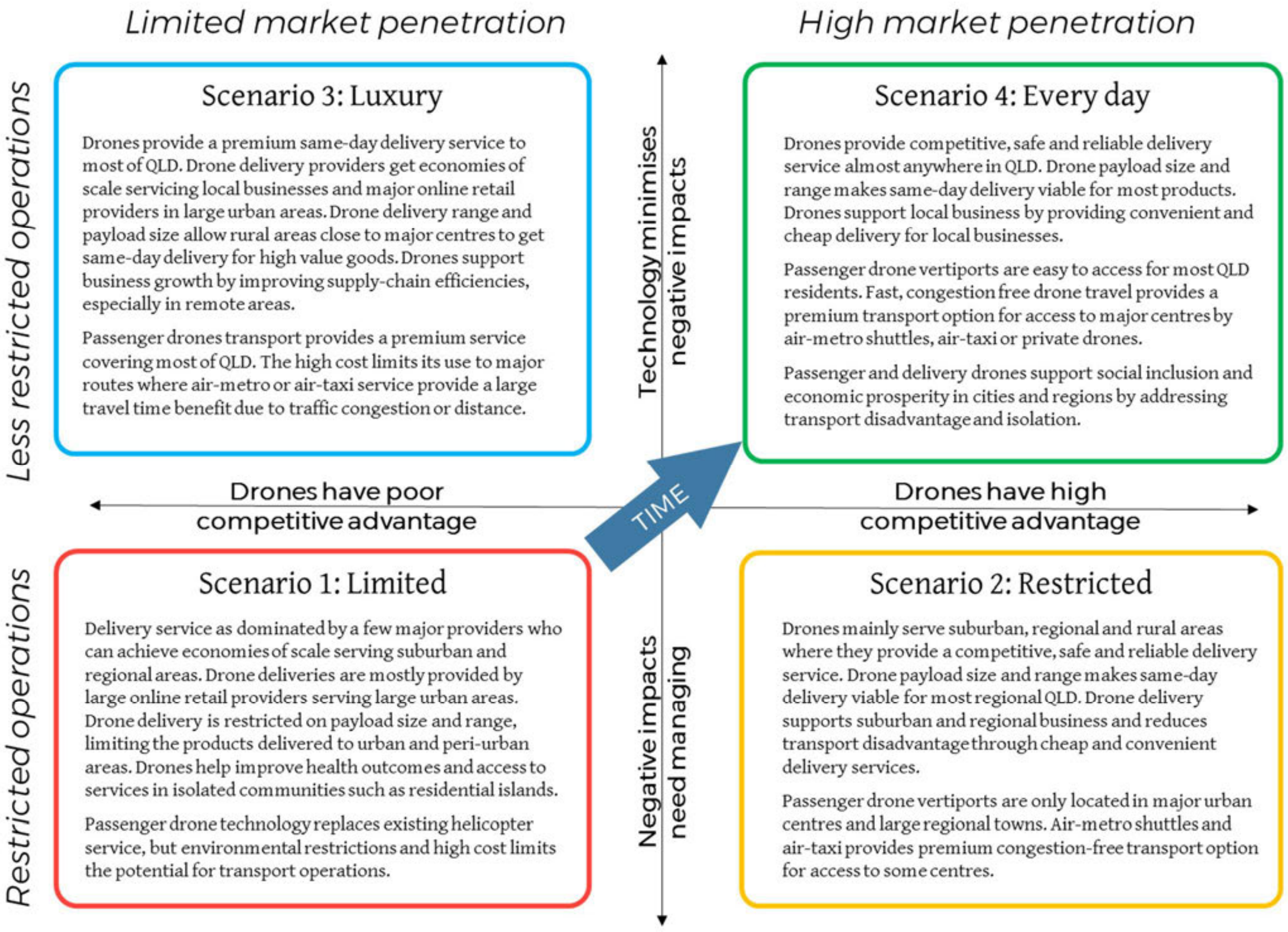
4 SCENARIOS FOR THE FUTURE

4.1 FUTURE SCENARIOS

Four potential scenarios were developed to test the implications of alternative futures. The scenarios are not a prediction of the future, but rather a way to identify potential future issues and opportunities.

The cost of drone transport is projected to reduce over time. The relative cost of drone service compared with other competing transport modes will affect how people choose to use drone services. Competing modes would include autonomous vehicles, improved public transport, and electric mobility and micro-mobility using an active travel network with enhanced safety and connectivity.

Drone technology improvements over time are likely to result in a shift towards fewer regulatory restrictions on drone use as the safety and reliability of drones is demonstrated. However, the extent of drone restrictions will heavily depend on how drone technology minimises negative impacts on the community and environment.



Scenario 3: Luxury

Drones provide a premium same-day delivery service to most of QLD. Drone delivery providers get economies of scale servicing local businesses and major online retail providers in large urban areas. Drone delivery range and payload size allow rural areas close to major centres to get same-day delivery for high value goods. Drones support business growth by improving supply-chain efficiencies, especially in remote areas.

Passenger drones transport provides a premium service covering most of QLD. The high cost limits its use to major routes where air-metro or air-taxi service provide a large travel time benefit due to traffic congestion or distance.

Scenario 4: Every day

Drones provide competitive, safe and reliable delivery service almost anywhere in QLD. Drone payload size and range makes same-day delivery viable for most products. Drones support local business by providing convenient and cheap delivery for local businesses.

Passenger drone vertiports are easy to access for most QLD residents. Fast, congestion free drone travel provides a premium transport option for access to major centres by air-metro shuttles, air-taxi or private drones.

Passenger and delivery drones support social inclusion and economic prosperity in cities and regions by addressing transport disadvantage and isolation.

Scenario 1: Limited

Delivery service as dominated by a few major providers who can achieve economies of scale serving suburban and regional areas. Drone deliveries are mostly provided by large online retail providers serving large urban areas. Drone delivery is restricted on payload size and range, limiting the products delivered to urban and peri-urban areas. Drones help improve health outcomes and access to services in isolated communities such as residential islands.

Passenger drone technology replaces existing helicopter service, but environmental restrictions and high cost limits the potential for transport operations.

Scenario 2: Restricted

Drones mainly serve suburban, regional and rural areas where they provide a competitive, safe and reliable delivery service. Drone payload size and range makes same-day delivery viable for most regional QLD. Drone delivery supports suburban and regional business and reduces transport disadvantage through cheap and convenient delivery services.

Passenger drone vertiports are only located in major urban centres and large regional towns. Air-metro shuttles and air-taxi provides premium congestion-free transport option for access to some centres.

MODELLING FUTURE DRONE TRANSPORT DEMAND

A conceptual model of the four scenarios was developed for the South East Queensland Region using existing data, population and travel behaviours. The state's 2036 population and travel projections were used to estimate possible future demand. Data sources used included:

- Australia Post parcel deliveries
- Café, restaurant and takeaway turnover
- Department store sales data
- SEQ Strategic Transport Model.

Assumptions made for the concept model development are documented in Appendix A. They were based on a literature review of current trends and future projections of how drone transport may change current travel behaviours and purchasing behaviours.

The conceptual model has very limited evidence to verify the validity of assumptions. It should therefore not be seen as an accurate prediction of the future, but rather a test of plausible future scenarios.

The model did not investigate how passenger drones may change where people choose to live and work, or the new trips generated due to drone travel's ease and convenience. Nor did the model undertake an economic analysis of how reducing the cost of same-day goods delivery may change customers' purchasing behaviours.

The model assumed likely locations for drone vertiports and delivery hubs based on existing and planned land uses and their proximity to potential customers. Alternative locations could change the number and distribution of drone trips.

The model assumed that point-to-point travel (as the crow flies) was available for all scenarios. It is recognised that airspace restrictions could affect drone flight paths, but modelling the current restrictions would severely restrict the potential for passenger and delivery drone transport services in much of the urban areas of SEQ.

SCENARIO IMPLICATIONS

The four scenarios were analysed for the year 2036 to identify how the scenarios would influence:

- number of drone trips made
- the distance travelled by drones
- the vehicle kilometres saved.

The modelled drone scenarios were mapped and trends noted in the distribution of demand. Key trends and insights gained from the conceptual modelling of the four drone transport scenarios are discussed in the following sections.

4.2 TRANSPORT IMPLICATIONS

The total drone demand for the four scenarios ranges from 100,000 to 300,000 daily trips with 45% to 65% of drone trips for food deliveries.

Delivery by drone would not always significantly reduce vehicle kilometres travelled. Same-day delivery of online purchases would typically replace current delivery services where multiple deliveries are made by a single vehicle to ensure cost efficiency. The vehicle kilometres saved by moving to drone delivery would therefore not directly equate to the drone kilometres travelled.

Drone delivery of takeaways would replace customer pick-up or existing delivery services. Drones were assumed to only serve trips more than 1 km long. They would therefore mostly replace motor vehicle delivery, but could also replace bicycle delivery. Therefore, the distance drones travel to deliver takeaways is similar to the reduced vehicle kilometres travelled.

The approach to estimating the vehicle kilometres saved is described in Table A2 in Appendix A (page A-3).

Travel by passenger drone is assumed to cost at least US$30 per trip (McKinsey & Company, 2018). This high cost limits the potential demand for passenger drones with the maximum demand projected to be up to 4,000 daily trips. The scale of demand is similar to the number of daily trips to work by ferry in Brisbane.

Passenger drones could offer significant time savings during commuter peak periods. The travel time benefit would be most significant for trips of longer distances on corridors with high traffic congestion levels. Passenger drones would also provide a travel time reliability benefit over peak hour driving. Relatively short trips to the islands of Moreton Bay would also benefit significantly from passenger drone transport.

By 2036, almost 20 million vehicle trips per day are projected for the road network in SEQ (SEQ Strategic Transport Model). The demand modelling shows that the total number of drone trips per day would therefore be 0.5% to 1.4% of the daily trips made in SEQ in 2036.

By 2036, vehicles will travel almost 140 million kilometres per day on the SEQ road network (TMR, 2019). The demand modelling shows that drone transport will therefore only save up to 1.2% of daily vehicle kilometres travelled in SEQ.

The scenario modelling shows that drone transport will likely have limited ability to reduce traffic congestion in SEQ. Drone transport does however deliver value by making it possible to bypass traffic congestion for trips with a high time value. Drone transport service can also benefit island communities and outer suburban areas with high levels of car dependence.

Table 4.1 Transport statistics for modelled scenarios

DRONE TYPE	DAILY STATISTIC	SCENARIO 1: LIMITED DRONE SERVICE	SCENARIO 2: RESTRICTED DRONE SERVICE	SCENARIO 3: LUXURY DRONE SERVICE	SCENARIO 4: EVERY DAY DRONE SERVICE
Delivery drones	Total trips made	108,000	201,000	229,000	278,000
	Total trip distance (km)	1,686,000	2,880,000	4,431,000	3,702,000
	Average distance (km)	16	14	19	13
Passenger drones	Total trips made	0	1,000	1,000	4,000
	Total trip distance (km)	0	23,000	30,000	91,000
	Average distance (km)		23	30	23
All drones	Total trips made	108,000	202,000	230,000	282,000
	Total trip distance (km)	1,686,000	2,903,000	4,461,000	3,793,000
	Average distance (km)	16	14	19	13
Road network benefits	Reduction in total vehicle travel distance (km)	801,000	1,747,000	1,100,000	1,568,000

DISTRIBUTION OF DRONE DEMAND

Drone delivery service offers most benefit to lower-density areas where transport disadvantage is high. This can be seen clearly when examining the demand distribution for drone takeaway delivery – where the demands are high, the delivery distances are relatively short (between 1 km and 5 to 15 km, depending on the scenario), and there are many service locations throughout SEQ.

Takeaway delivery by drone generates between 45% and 65% of drone trips in the four scenarios. This demand's distribution shows a concentration in suburban areas, with lower demand within central Brisbane.

Although central Brisbane has more residents, the large number of restaurants would make other delivery options more cost effective than drones. The higher residential densities in the inner-city also makes direct delivery to the customer more challenging, further reducing drone delivery's relative attractiveness.

In suburban areas, the longer distances to restaurants and the low development density gives delivery drones a distinct advantage over land-based delivery.

The distribution of demand is relatively constant for all scenarios. For scenarios 1 and 2 the longer delivery distance (up to 15 km) results in greater overlap in deliveries than for the other scenarios where delivery distance was limited to a maximum of 5 km.

The distribution of demand shown in Figure 4.1 assumes takeaway delivery drones serve a catchment of up to 15 km. This makes it feasible for businesses in regional centres to serve surrounding rural properties. It also means that in suburban areas there is potential for residents to choose between multiple different restaurants.

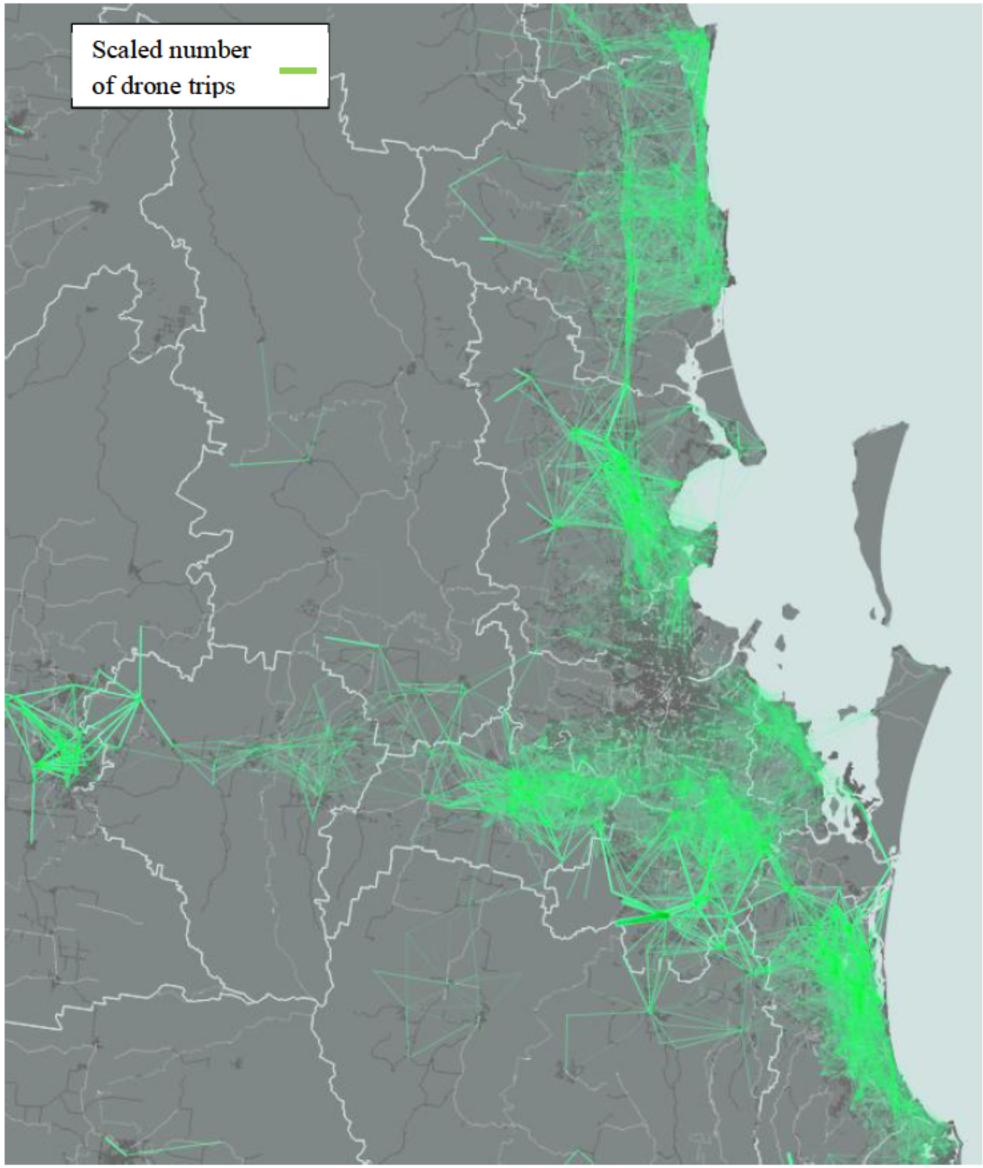


Figure 4.1 Local takeaways delivery: Scenario 2

DRONE DELIVERY HUB USAGE

The scenarios assumed drone delivery would be from three different locations based on delivery type:

- **Direct distribution hubs** located to ensure most urban SEQ residents are within 20 km radius of at least one delivery hub. Twenty-one locations identified in existing or planned industrial areas.
- **Shopping centre distribution hubs** located at shopping centres throughout SEQ. Forty-two locations identified at existing or planned shopping centres.
- **Food delivery hubs** located where there are takeaway outlets or restaurants. For the analysis, post offices were used as a proxy for these locations.

The number of trips per drone delivery hub per day is shown in Figure 4.2 for Scenario 4 (every day). The busiest drone goods delivery hubs are projected to be in outer suburban and rural areas (Jimboomba, Upper Coomera, Mount Crosby). The busiest of these locations had an average of up to 100 drone trips an hour.

The busiest drone delivery hubs for food are projected to be in outer suburban areas (Upper Coomera, Yarrabilba, Park Ridge). The busiest of these locations had an average of up to 270 drone trips per hour.

The busiest drone distribution hubs are located within outer suburban areas and rural service centres because the inner urban areas have more distribution hubs with overlapping catchments.

The modelling assumed a large number of drone delivery hubs spread throughout SEQ. This limited the demand at any one delivery hub. The four scenarios varied the number of goods delivery hubs by including or excluding the shopping centre distribution hubs. More radically altering the business model would increase the number of trips served by the busiest distribution hub.

The number of drone delivery hubs would have a significant implication for the number of trips from each, and hence the noise each hub would generate.

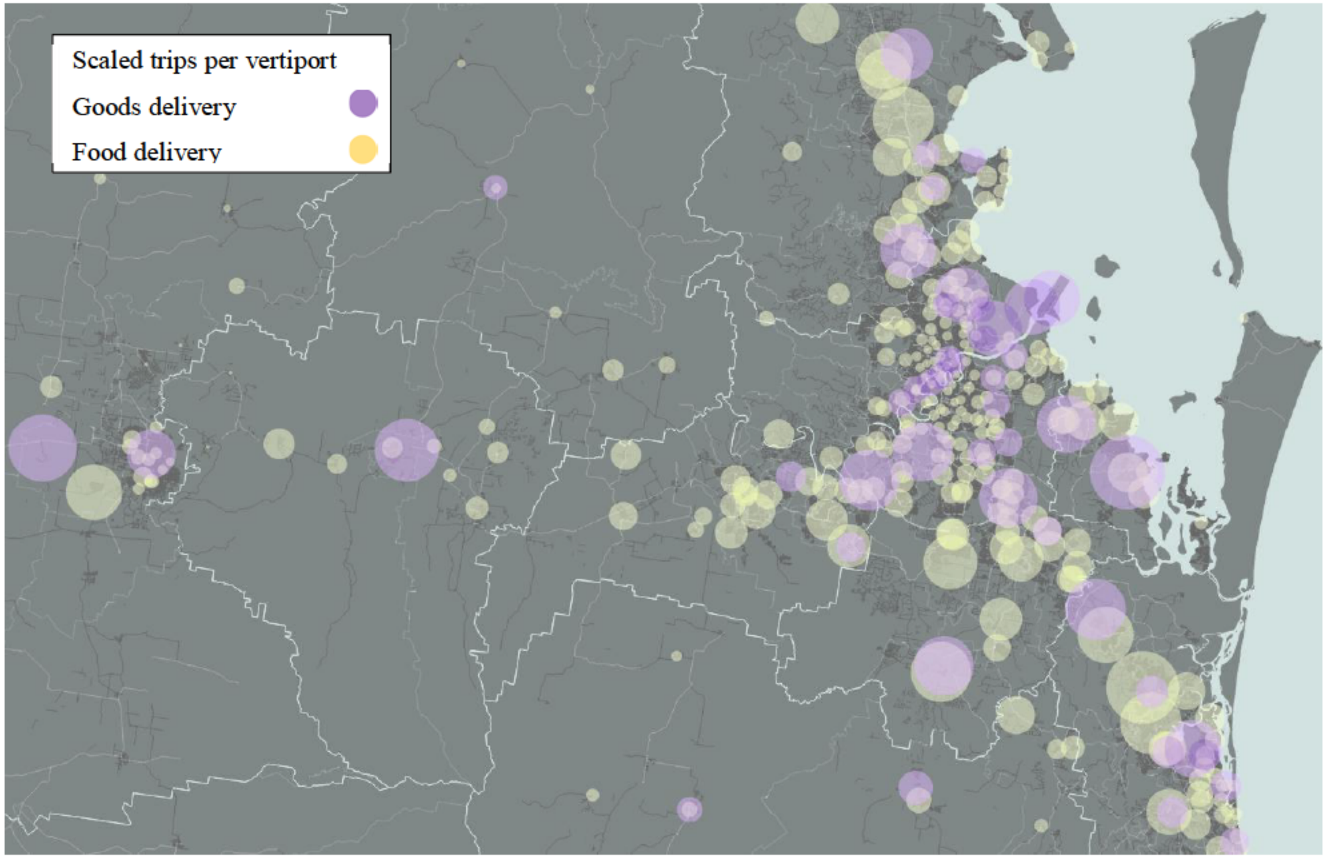


Figure 4.2 Vertiport and delivery hub use: Scenario 4

COMMUNITY IMPACTS

Drones’ noise impacts are a major concern for communities. The noise generated in SEQ by 100,000 to 280,000 drone trips per day would be low compared to the noise from 20 million vehicle trips per day. However, drone noise is different from traffic noise and would potentially impact areas that don’t currently experience much traffic noise. Drone noise would therefore be noticeable as ambient noise levels would be low.

The number of drone trips from a vertiport or drone delivery hub would provide a proxy measure of the potential noise generated at these locations. The noise impact of a vertiport or delivery hub will increase as the number of drone trips increases.

Up to five drone delivery trips per minute were estimated for the busiest drone delivery hub. The number of trips per delivery hub very much depends on the delivery model assumed. With a more consolidated delivery model serving a larger area (as in Scenario 3), the number of drone trips per drone hub is highest. Where more drone delivery hubs are provided (as in Scenario 4), they serve a smaller catchment and the number of drone trips is lower.

Minimising the number of drone delivery hubs serving an area can reduce the number of residents impacted by drone noise, but will increase each hub’s impact intensity.

The flight paths for drones would also result in noise impacts to communities. Figure 4.3 shows that most drone trips would be concentrated over populated areas. Drones generate less noise in flight than when hovering. The noise impact would therefore depend on both the route the drone takes, and the time hovering at its destination.

Further analysis of drone noise impacts is needed to identify the cumulative impact of drone noise, and the thresholds for acceptable noise impacts.

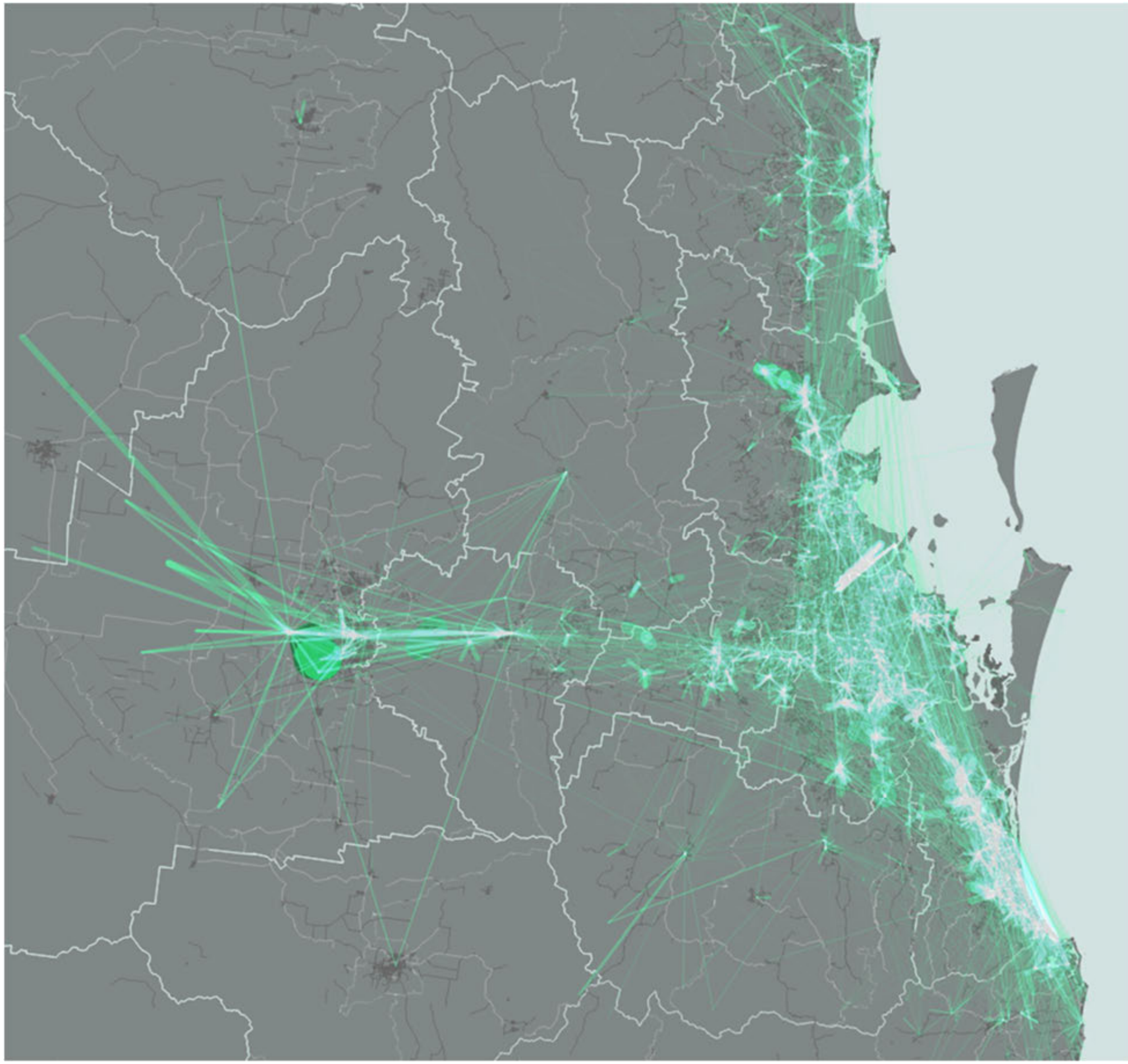


Figure 4.3 Maximum drone delivery demand in SEQ: Scenario 4

AIR METRO DEMAND

The air-metro concept was based on several assumptions that were informed by several international studies. The service would use four-seater passenger drones on a route structure connecting major destinations, as illustrated in Figure 4.4. For the model it was assumed that vertiports would be in areas with high potential demand for discretionary travel where customers would be willing to pay a premium price.

Figure 4.5 illustrates the daily demand at air-metro vertiports for Scenario 4, which has the highest demand level. The modelling found a consistent demand pattern at the air-metro vertiports in all scenarios. The five vertiports serving central Brisbane would together have the highest demand level. Providing five vertiports in central Brisbane would make the air-metro very accessible, but would also significantly increase the infrastructure cost. The Brisbane airport and cruise ship terminal would have the next highest potential passenger drone demand.

Toowoomba showed the lowest demand level. However, this is due to Toowoomba's existing high self-containment levels, and the distance between Toowoomba and Brisbane. The concept model did not account for the potential latent demand that a fast and reliable drone service could release on this and other routes.

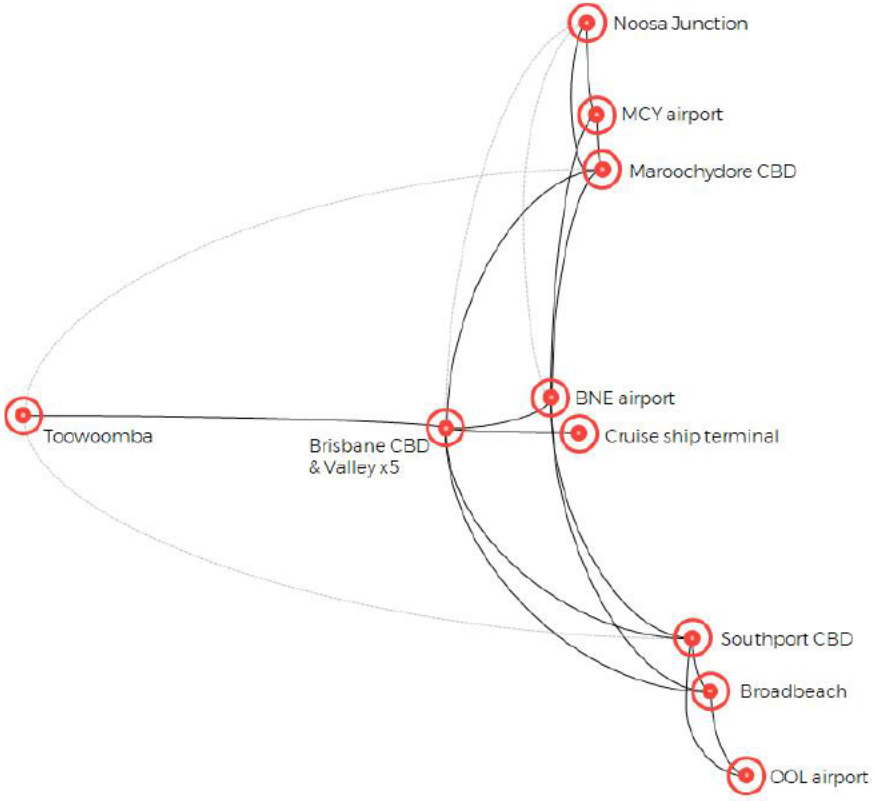


Figure 4.4 Air Metro network concept

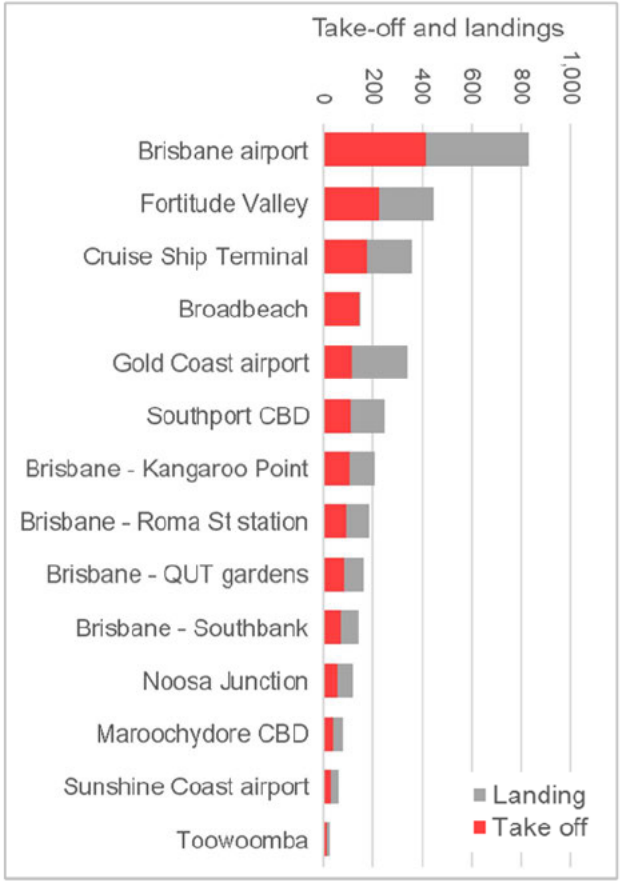


Figure 4.5 Air Metro vertiport daily demand

AIR TAXI DEMAND

The modelled scenarios varied the number of vertiports serving air-taxi and private passenger drones. Scenario analysis showed a relationship between the number of vertiports and the trips made using air-taxi or private passenger drones.

As the number of vertiports increases, demand increases as accessing passenger drones becomes more convenient. As the number of vertiports increases, the average use of vertiports gradually plateaus as some vertiports have high use, while others have very limited use.

In urban areas, passenger drones will need vertiports to ensure safety and minimise noise impacts. Widespread passenger drone use would need an extensive network of vertiports. If the users are covering the costs of building and maintaining these vertiports, costs would increase and suppress demand for urban travel via air-taxi and private passenger drones.

Without government funding of vertiports, passenger drones are expected to serve a small niche market. Even with government funding, the low passenger carrying capacity of passenger drones would limit the ability to deliver efficient transport services for a mass market.

TRAVEL TIME BENEFIT

Passenger drones provide a distinct travel-time advantage over car travel, particularly in peak periods. Figure 4.7 compares the travel times for private passenger drones (including time to access the vertiport) with projected peak-hour car travel times for the same destinations.

Some trips made by passenger drone would be slower than the equivalent trip by car, because of the time lost in accessing the vertiport in areas outside main centres.

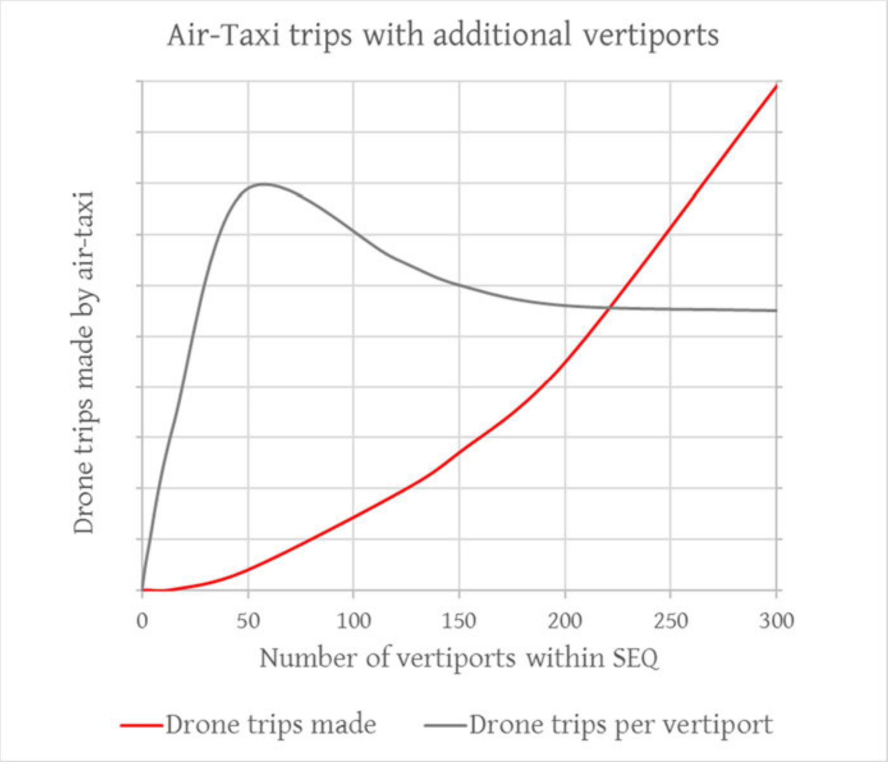


Figure 4.6 Relationship between passenger drone trips and the number of vertiports

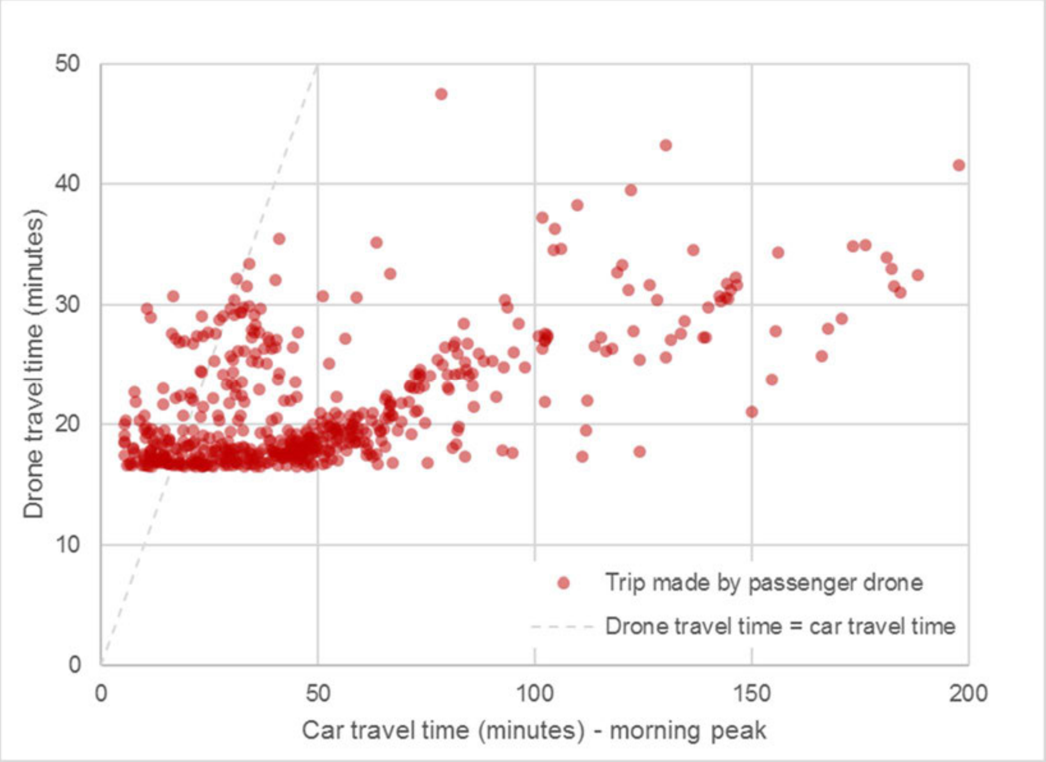


Figure 4.7 Travel time benefit of passenger drones

DISTRIBUTION OF PASSENGER DRONE DEMAND

The modelled demand for all passenger drone demand is shown in Figure 4.8 for the ‘every day’ drone scenario (Scenario 4). This shows the highest passenger drone demand and the most vertiport locations.

The other scenarios have fewer vertiports, resulting in less demand and fewer corridors serving passenger drones.

Brisbane airport was identified as the main destination for private passenger drones, serving 83% of trips. The demand between the Brisbane airport and central Brisbane was the major demand pair found. Drone trips to the Brisbane airport averaged between 60 and 115 per hour.

The Gold Coast was the destination with the next highest demand. Most of this demand connects the airports with main holiday centres.

Outside the major centres, the analysis found that passenger drone demand is very low, despite the relatively high density of vertiports in the ‘every day’ drone demand scenario.

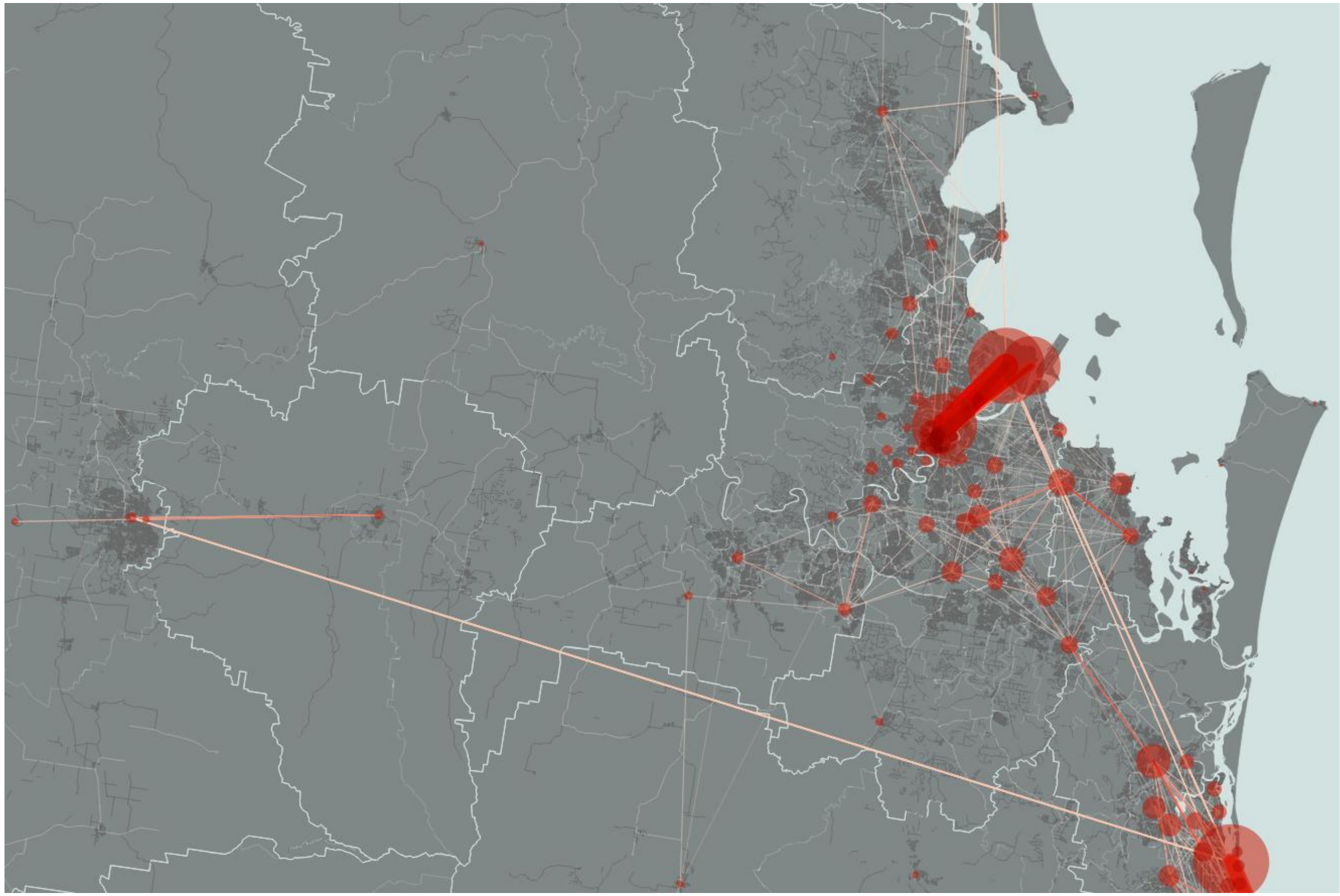


Figure 4.8 Distribution of passenger drone demand: Scenario 4

DRONE NO FLY ZONE

Air Services Australia has defined drone no-fly zones within 5.5 km of airports or aerodromes. Figure 4.9 shows the airport drone no-fly zones in central Brisbane, overlaid on the daily drone demand plots for all passenger and delivery drones in Scenario 4.

This illustrates that delivery and passenger drone demand would cross the airport drone no-fly zones. Passenger drone travel would be particularly impacted by this restriction as most passengers would have an origin or destination within the drone no-fly zone surrounding Brisbane airport.

The restricted airspace surrounding Archerfield airport would predominantly affect delivery drones. These restrictions would similarly impact drone transport services throughout Australia.

In addition to the airspace restrictions around airports, helicopter landing sites also have a 5.5 km zone surrounding them restricting commercial drone flights. Although not banned, care is required when operating drones within this zone. All central Brisbane lies within 5.5 km of helicopter landing sites, potentially limiting drone transport operations.

Queensland legislation restricts drone flights over state transport corridors. These would further restrict drone transport services to only short trips within areas surrounded by state transport corridors.

The current airspace restrictions would make drone transport operations unfeasible in central Brisbane and most other centres in Queensland. These restrictions would need addressing if drone transport is to be viable in most Queensland cities. Drone transport will be restricted to suburban and rural areas until air traffic control systems can safely manage drone traffic close to airports, aerodromes and helicopter landing sites.

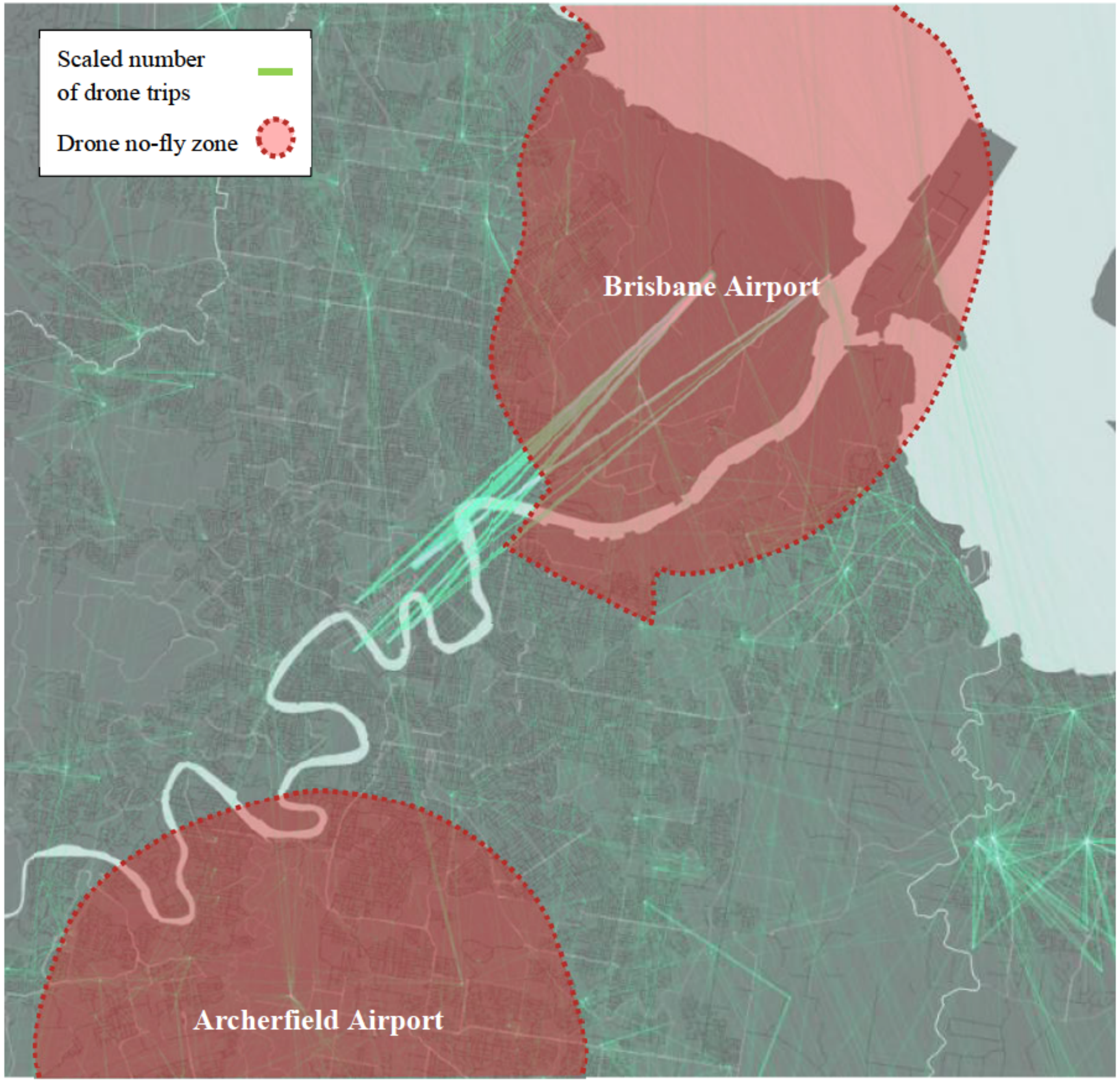


Figure 4.9 Central Brisbane total drone trips and airport drone no-fly zones

HEALTH SERVICE BENEFITS

Drones can provide a valuable role in improving health services. This could include rapidly transporting urgent equipment, products or test samples:

- between doctors and pathology labs or hospitals
- between hospitals
- directly to emergency locations.

This function’s conceptual modelling assumed this service would cater to clinics at least 5 km from a hospital. The model assumed 5 to 10 deliveries per day between doctor clinics and the nearest hospital, and 10 to 20 trips per day between hospitals.

Delivering medical items to emergency locations was not modelled as its random nature makes it difficult to estimate. It is expected that regional hospitals would most benefit from this service due to the large service areas.

Figure 4.10 shows the potential demand serving hospitals for the highest demand scenario. This demand pattern is similar to other scenarios. Hospitals on the SEQ outer edges were found to attract the largest trip volumes as there are fewer hospitals serving a dispersed population.

QE2 Jubilee Hospital in the Brisbane’s south and Prince Charles Hospital in the north are centrally located between multiple hospitals, as Figure 4.11. shows. This accounts for the high trip numbers serving these two hospitals. Both are small hospitals and this demand level would not match their current function. Their location gives them a potential advantage as a logistics hub for drone transport serving surrounding hospitals and clinics.

The validity of the assumptions would need testing using actual data on transporting medical equipment, products and test samples.

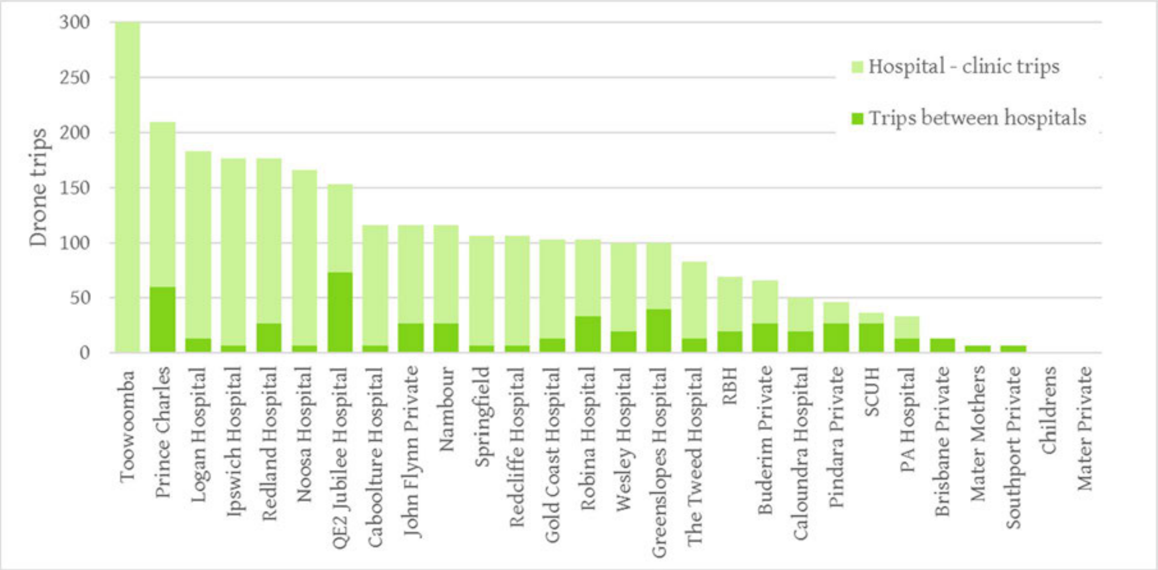


Figure 4.10 Delivery demand per hospital: Scenario 4

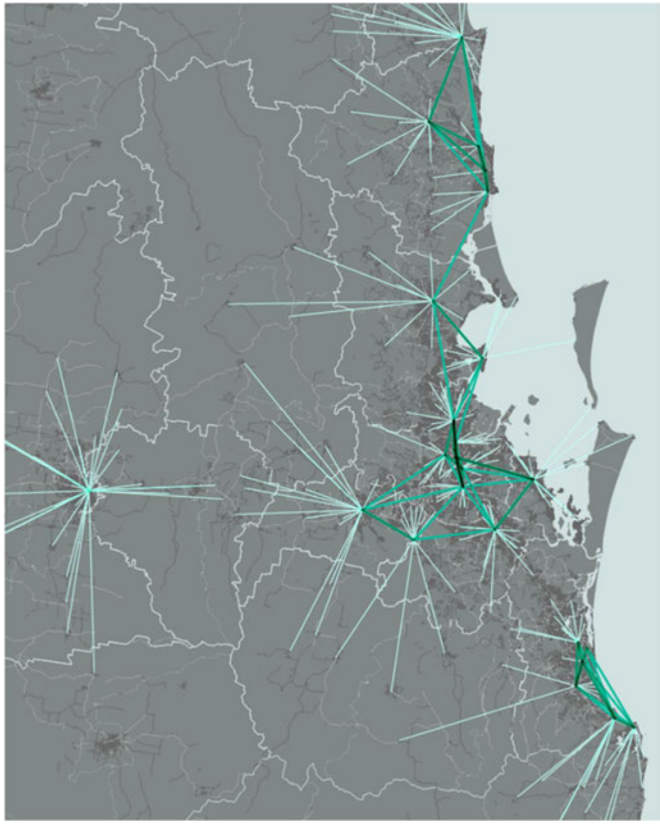


Figure 4.11 Health drone transport demand example

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 IMPLICATIONS OF FINDINGS

The policy implications coming from the investigation can be summarised as follows.

Drones could help address transport disadvantage in outer suburban, rural and island communities

Low-density outer suburban areas, island communities and rural properties have high levels of car dependence, long distances to travel or difficulty in making trips. Delivery drones could improve the ease and reduce the cost for customers in these communities to buy goods and food. The isolation from commercial centres and the low density of demand provide a distinct competitive advantage for drones over other modes of transport.

Drone delivery service could reduce the need for private mobility in transport disadvantaged locations by providing a viable transport alternative. Delivery drones also have great potential to support positive health outcomes in remote communities by reducing the cost and delay to transport test samples, equipment and medication. The high cost of passenger drones limits the potential of this mode in addressing transport disadvantage.

Drone transport services are not likely to relieve congestion on QLD's land transport network

Delivery drones and passenger drones are only expected to reduce daily vehicle kilometres travelled in SEQ by up to 1.2%. As most drone trips made are expected to serve suburban areas, the reduced vehicle travel will therefore primarily not be on congested corridors.

Although passenger drones will provide a high travel time benefit to users of congested corridors, their high cost and limited landing locations would restrict the potential for any significant congestion benefit.

Existing aviation regulation and infrastructure could limit the scale of drone transport services

Existing federal aviation regulation and governance structures focus on long-distance aviation activities and are not equipped for highly-localised urban drone transport. The regulation of airspace, including the current drone no-fly zones, and the current aviation infrastructure is not equipped for a large increase in urban aviation that could arise from delivery and passenger drones.

Currently, State and Local Governments do not have regulatory responsibility for most aviation activities. Drone transport innovations are facilitating disruptive change in the field of aviation and all tiers of government need to contribute to revisiting existing regulation and infrastructure to support positive outcomes for the community from drone transport service.

Noise and environmental impacts of drone transport technology is poorly understood

Recent trials of drone deliveries in Canberra have highlighted community concerns about the noise, privacy and environmental impact of drones. However, recent trials in Logan have not yet resulted in a similar level of community concern. The impacts of transport drones on communities and the environment is not well understood as there is no long-term research on this new application for drone technology.

There is a need for research into the impacts of transport drones and the appropriate controls required to minimise negative impacts while not preventing the benefits of drone transport in Queensland communities.

The current trial of delivery drones in Logan presents an opportunity for research into the impacts of delivery drones on the community and environment.

There are no land use planning instruments appropriate for regulating the use of land for delivery drone hubs or passenger vertiports

The location of drone hubs and vertiports will have a major influence on the potential for delivery and passenger drones to provide a viable service to communities. However, drone hubs and vertiports will generate noise impacts on surrounding land uses, depending on the level of use of the facility.

There are currently no land use planning instruments available for local government to regulate the use of land as a drone delivery hub or vertiport. There is a need for a classification system for drone noise to inform the development of appropriate land use policy for drone delivery hubs and vertiports.

Research into the extent of noise impact of drone delivery hubs and vertiports needs to underpin the development of land use policies.

5.2 FURTHER INVESTIGATION

The findings of the project highlighted the need for further investigation into the following policy areas.

DRONE NO-FLY ZONES

Commercial operation of delivery and passenger drones in Queensland would need no-fly zones to be relaxed to allow these drone services to operate within controlled air-space and over major road and waterway corridors.

CASA and Air Services Australia are investigating how they regulate commercial drone operations within controlled airspace. Queensland should contribute to these discussions as they represent significant implications for the viability of transport drones in Queensland centres.

TMR regulation of drone operation over state transport corridors could have significant implications for the viability of commercial drone transport services in Queensland. There is a need to revisit this policy to ensure it ensures the safe operation of the road network, without compromising the potential for the commercial operation of transport drones.

DRONE IMPACTS ON THE COMMUNITY AND ENVIRONMENT

There is limited research into the community and environmental impacts of noise from drones. There is a need to research and define thresholds for acceptable noise impacts to inform an assessment of acceptable drone service levels over areas and at vertiport or delivery hubs.

The Federal Department of Infrastructure, Regional Development and Cities regulates aircraft noise and is currently developing appropriate standards for drones. State and local governments need to investigate their role in facilitating the benefits of drone transport for communities while regulating the impacts on local communities and environments.

LAND USE POLICY

There is a need for appropriate planning instruments to be developed to manage the use of land for drone delivery hubs, as they would fall below the thresholds for helicopter landing sites.

Any proposed planning instruments for regulating land development for drone delivery hubs would need to consider the potential impacts of drone delivery hubs on the community and environment, as well as the role they can play in addressing transport disadvantage.

POLICY AND PLANNING FOR DRONE TRANSPORT

State and local authorities need to investigate the role delivery drones and passenger drones could play within cities, regional centres and rural communities. Policy, strategy and planning for drone transport should consider:

- the role of state and local governments in planning and regulating delivery drones
- the role delivery drones should play in addressing transport disadvantage
- the potential for delivery drones to improve health services in regional and remote communities
- how drone delivery services should be structured to best support local business
- the impacts on surrounding road networks of drone delivery hubs and passenger vertiports
- the role passenger drones should play in the multi-modal transport network
- the role of local and state government in supporting a possible future role for drones in passenger transport
- the optimal locations for future vertiports and the need for governments to help facilitate their development.

5.3 CONCLUSION

This investigation identified the potential opportunities and risks apparent from current trends, and possible future scenarios for drone transport. Although this analysis focussed on South East Queensland, drones have great potential to address transport challenges in regional and remote communities throughout Queensland.

The report does not aim to accurately predict the future. Instead it provides a common starting point for conversations within government, with business, and with the community. These conversations will help shape policy on state and local government roles in planning, regulating and facilitating the use of drone technology to address Queensland's transport challenges.

The following actions are recommended to inform these discussions and best position Queensland to benefit from drone transport opportunities.

- investigate opportunities to facilitate drone delivery services and health-related drone services for transport disadvantaged and regional communities.
- the case for drone transport is unlikely to be built on the congestion reduction benefits. Support for drone transport initiatives should be built on other benefits realised by drones.
- **S**tate and Local Government in Queensland needs to engage with Federal regulators of aviation to appropriately position the state to maximise the potential for drones in Queensland.
- the Logan trial of delivery drones presents an opportunity for Queensland research into the impact of transport drones on the community and the environment.
- **S**tate and Local Government should collaborate to develop suitable planning instruments for Local Government use in regulating the development of land as drone hubs or vertiports.

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Appendix A

Assumptions and Results

A1 INPUTS AND ASSUMPTIONS

The conceptual model for drone transport was built using available public data sources. This included existing and future projects for demographics, trade and transport topics' data from TMR and Australian Bureau of Statistics.

Given the nature of the modelling and budget constraints, numerous assumptions were needed to develop the model. The model features are illustrated in the model framework mind map shown in Figure A.1.

The model's primary assumption is that it is a 'scenario assessment tool'. The model does not include aspects such as modal choice, and therefore does not incorporate any equilibrium or convergence.

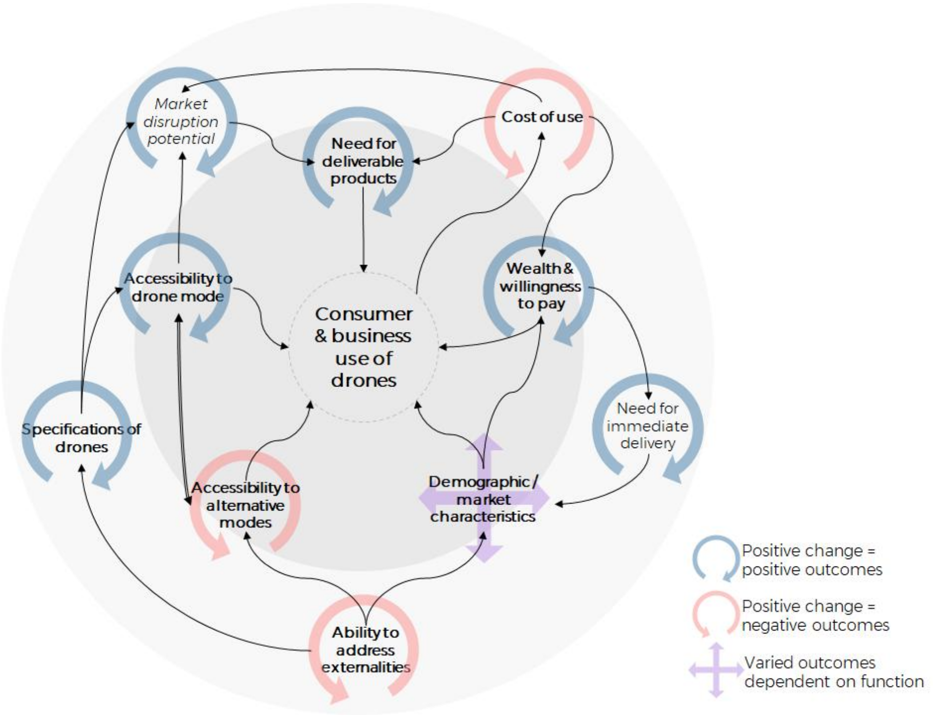


Figure A.1 Drone conceptual model mind map

Table A.1 summarises the data inputs and their use in the conceptual model.

Table A.1 Conceptual model data inputs

DATA SOURCE	HOW USED
Multi-modal South East Queensland Strategic Demand Model (SEQSTM): — Private vehicle demands — Public transport demands — Demographics — Private vehicle travel time (morning peak hour)	Data from the 2036 scenario were extracted and used to inform the basis of demand generation and distribution for passenger drones only. Private vehicle travel times were used to compare travel times estimated for drone trips.
2019 Australia Post locations	Used as a proxy location for: Local centres with takeaway restaurants Local centres with a doctors' surgery or clinic
Hospital locations	Used to inform the locations/sources of demands for specialty delivery trips
Australia post national parcel delivery demands	Used to inform the demand for parcel delivery
Australian Bureau of Statistics (ABS) consumer behaviour: — Food/consumables — Department store sales — Income	Data used to inform the total market demand for various functions. Assumed trip rates of: $100 retail purchase/drone trip $20 takeaway purchase/drone trip
ABS SA2 boundaries	Basis of model zoning system

Table A.2 and Table A.3 summarises the key assumptions made to model the scenarios.

Table A.2 Conceptual model assumptions

ASSUMPTIONS	HOW USED
Trip production	Based on population for drone services to customers, and employment for drone services to businesses.
Demand distribution functions	Metrics associated with accessibility, density and relative income used to scale demands within the SA2 boundaries
Annual-to-day conversion	Annual-to-day demands are scaled based on typical ratios of 1:250 (5-day weeks) or 1:300
Drone market share	A percentage of the total market was assumed to be captured via the drone market. This variable changes among the scenarios
Drone operating distance	Operating ranges (minimum and maximum) were established for each function based on: Competition against other modes (e.g. walking) Assumed future technology capabilities Assumed limits to operating range
Drone operating speed	Speed of 100 km/h assumed in the comparative travel time analysis. This assumption was informed by data from existing trials
Number of parcels per drone	Generally assumed as one parcel per drone delivery trip.
Number of passengers per drone	Air-metro service = 4 passengers Air taxi and private drone travel = 1 passenger
Trip ‘assignment’	A straight-line between production and attraction was assumed. Drone no-fly zones were not considered
Trip production/attraction	Drone trips were assumed to be generated from the nearest production source within the range. If multiple sources exist, trips are divided evenly.
Operating model	For parcel and food delivery, drones are assumed to return empty to their base after each delivery. For passenger drones, generally trips are ‘one-way’ with the same vehicle being used for subsequent services. The model does not consider asymmetry in demand. Specialty delivery assumed to operate like a service with a schedule carrying multiple items rather than an ‘on demand’ delivery catering for individual items
Cost of use of the drone	Not explicitly considered in the model, but considered via the ‘income’ and scaling factors

ASSUMPTIONS	**HOW USED**
Location of drone distribution centres	Drone delivery hubs identified based on existing or planned industrial areas and shopping centre locations serving existing and future growth areas
Location of passenger vertiports	Established based off likely centres for demand such as airports, business centres, major activity centres, major public transport stations, and major tourism destinations. Also, included regional locations where demand may be generated due to distance from centres or transport constraints, such as island communities.
Vehicle kilometre savings	The assumptions for estimating vehicle kilometre savings (VKT) from drone transport were calculated based on overarching assumptions applied to each function. These assumptions were developed in consideration of the following factors: — Number of parcels delivered per trip for current practice vs drone vehicles — The vehicles which drones would typically replace, including consideration of active modes (especially for food deliveries) — The likely percentage saving in land base travel distance if the trip is made by drones – reduces as distance increases — The operational assumptions associated with drone transport vs current transport For each of the goods transport functions, the VKT savings for traditional vehicles versus the delivery distance of drones (including delivery and return trip) were: — Function 1 (local courier service) = 5% (limited savings in vehicle kilometres as courier and parcel delivery services consolidate deliveries to have high efficiencies through minimising kilometres travelled) — Function 2 (local takeaways) = 75% (largely replaces a dedicated trip to deliver/pick up the item. Some active transport delivery replaced and short distances have potential for higher VKT savings) — Function 3&4 (delivery of online purchases) = 25% (replaces some trips to shops, but most assumed to replace efficient delivery by courier) — Function 6 (supply chain logistics) = 50% (smaller payload of drones and faster turnaround may mean more trips by drone) In the case of the health industry service (Function 7), no baseline data was available to inform an understanding of existing vehicle movements for transport of health related items between hospitals and clinics. Passenger drones (Functions 8,9 and 10) are assumed to generate a significant number of induced discretionary trips. The vehicle travel to access the vertiports for these discretionary trips are assumed to largely cancel out the VKT savings from trips shifting from vehicle-based trip to a passenger drone.

Table A.3 Conceptual model scenario assumptions

FUNCTION	SCENARIO 1: LIMITED	SCENARIO 2: RESTRICTED	SCENARIO 3: LUXURY	SCENARIO 4: EVERY DAY
Global assumptions common to all functions	**Accessibility function:** drone demand varies based on the ease of access to shops within the zone. **Population density function:** increased population density within a zone reduces the relative ease of drones servicing the zone. **Cost of use factor:** the average income of an area affects the drone demand dependent on the relative cost of drone transport. Scenario 1 and 2 have higher wealth factors, suppressing drone demand within areas with lower average incomes.			
Function 1: Local courier service	Drone range: 10 km Coverage: within 5 km of post office Market: Australia Post parcel deliveries/person/year (2018) Market share: 2%	Drone range: 10 km Coverage: within 5 km of post office Market: Australia Post parcel deliveries/person/year (2018) Market share: 4%	Drone range: 10 km Coverage: within 5 km of post office Market: Australia Post parcel deliveries/person/year (2018) Market share: 4%	Drone range: 10 km Coverage: within 5 km of post office Market: Australia Post parcel deliveries/person/year (2018) Market share: 6%
Function 2: Local takeaways	Drone range: 15 km Coverage: 1 km to 15 km of local takeaways (post office used as proxy location) Market: Takeaway purchases / person/year (2018) Market share: 2%	Drone range: 15 km Coverage: 1 km to 15 km of local takeaways (post office used as proxy location) Market: Takeaway purchases / person/year (2018) Market share: 4%	Drone range: 5 km Coverage: 1 km to 5 km of local takeaways (post office used as proxy location) Market: Takeaway purchases / person/year (2018) Market share: 4%	Drone range: 5 km Coverage: 1 km to 5 km of local takeaways (post office used as proxy location) Market: Takeaway purchases / person/year (2018) Market share: 6%
Function 3: Shopping centre distribution	Not included in scenario	Not included in scenario	Drone range: 60 km Coverage: within 5 km to 60 km of shopping centre drone hub Market: ABS Department Store sales turnover (2018) Market share: 2% (combined with Function 4)	Drone range: 60 km Coverage: within 5 km to 60 km of shopping centre drone hub Market: ABS Department Store sales turnover (2018) Market share: 4% (combined with Function 4)

FUNCTION	SCENARIO 1: LIMITED	SCENARIO 2: RESTRICTED	SCENARIO 3: LUXURY	SCENARIO 4: EVERY DAY
Function 4: Direct distribution	Drone range: 60 km Coverage: 5 km to 60 km of major drone distribution hub Market: ABS Department Store sales turnover (2018) Market share: 1%	Drone range: 60 km Coverage: 5 km to 60 km of major drone distribution hub Market: ABS Department Store sales turnover (2018) Market share: 3%	Drone range: 100 km Coverage: 10 km to 100 km of major drone distribution hub Market: ABS Department Store sales turnover (2018) Market share: 2% (combined with Function 3)	Drone range: 100 km Coverage: 10 km to 100 km of major drone distribution hub Market: ABS Department Store sales turnover (2018) Market share: 2% (combined with Function 3)
Function 5: Internal supply-chain logistics	Not included in scenarios as no suitable data source available to inform assumptions			
Function 6: External supply chain logistics	Drone range: 60 km Coverage: 2 km to 60 km of shopping centre drone hub Market: Assumption on trips per employee/year Market share: 0.5 drone deliveries/job/year	Drone range: 60 km Coverage: 2 km to 60 km of shopping centre drone hub Market: Assumption on trips per employee/year Market share: 2 drone deliveries/job/year	Drone range: 60 km Coverage: 2 km to 60 km of shopping centre drone hub Market: Assumption on trips per employee/year Market share: 2 drone deliveries/job/year	Drone range: 60 km Coverage: 2 km to 60 km of shopping centre drone hub Market: Assumption on trips per employee/year Market share: 4 drone deliveries/job/year
Function 7: Health industry service	Drone range: 60 km Coverage: Between hospitals only Market: inter-hospital transport Market share: 10 drone trips / hospital / day	Drone range: 60 km Coverage: Between hospitals only Market: inter-hospital transport Market share: 20 drone trips / hospital / day	Drone range: 60 km Coverage: 5 km to 60 km of hospital Market: inter-hospital transport and GP/clinics (post office used as proxy location) Market share: Hospital: 10 drone trips / day GP: 5 drone trips / day	Drone range: 60 km Coverage: 5 km to 60 km of hospital Market: inter-hospital transport and GP/clinics (post office used as proxy location) Market share: Hospital: 20 drone trips / day GP: 10 drone trips / day

FUNCTION	SCENARIO 1: LIMITED	SCENARIO 2: RESTRICTED	SCENARIO 3: LUXURY	SCENARIO 4: EVERY DAY
Function 8: Air metro	Not included in scenario	Drone range: 150 km Coverage: defined routes Market: SEQSTM total person trip/day with origin/destination 2 km from vertiport Market share: 2%	Drone range: 150 km Coverage: defined routes Market: SEQSTM total person trip/day with origin/destination 2 km from vertiport Market share: 2%	Drone range: 150 km Coverage: defined routes Market: SEQSTM total person trip/day with origin/destination 2 km from vertiport Market share: 3%
Function 9: Air taxi	Not included in scenario	Not included in scenario	Drone range: 150 km Coverage: 10 km to 150 km Market: SEQSTM person trip by car/day with origin/destination 2 km from vertiport Market share: 0.5%	Drone range: 150 km Coverage: 10 km to 150 km Market: SEQSTM person trip by car with origin/destination 2 km from vertiport Market share: 1%
Function 10: Private drone transport	Not included in scenario	Not included in scenario	Not included in scenario	Drone range: 150 km Coverage: 10 km to 150 km Market: SEQSTM person trip by car/day with no constraint on vertiport catchment Market share: 0.1%

A2 DRONE DELIVERY OF CONSUMABLES

The drone delivery of takeaway food (Function 2) was assumed to be based on a business model where multiple drone service centres would be established at locations where there are existing takeaway restaurants. Alternative business structures not modelled included:

- ‘dark kitchens’ established to exclusively serve drone delivery, with a limited number of drone delivery hubs providing very wide delivery area
- single drone delivery operator serving multiple restaurants throughout the city with delivery drones not tied to a single hub. Empty drones route to their closest delivery hub, not the original hub.

The four scenarios modelled varied the maximum range of the drones, and the percentage of the restaurant purchases delivered by drone.

A 1 km minimum distance was set for takeaway delivery by drone as other delivery modes or walk-in purchase was assumed to be more viable for shorter distances.

Between the four scenarios, the **flight range has the greatest influence** on the pattern of demand, and the potential saving in vehicle kilometres travelled.

The greatest demand for drone delivery of takeaways are areas within the range of the drone hubs that many residents but few restaurants.

Takeaway delivery by drone would compete directly with existing delivery services. The speeds achieved by drones would give them a distinct advantage over long distances, but restrictions on travel at night could limit demand.

Figure A.2 summarises the range in the number of trips (deliveries only) from each post office per day.

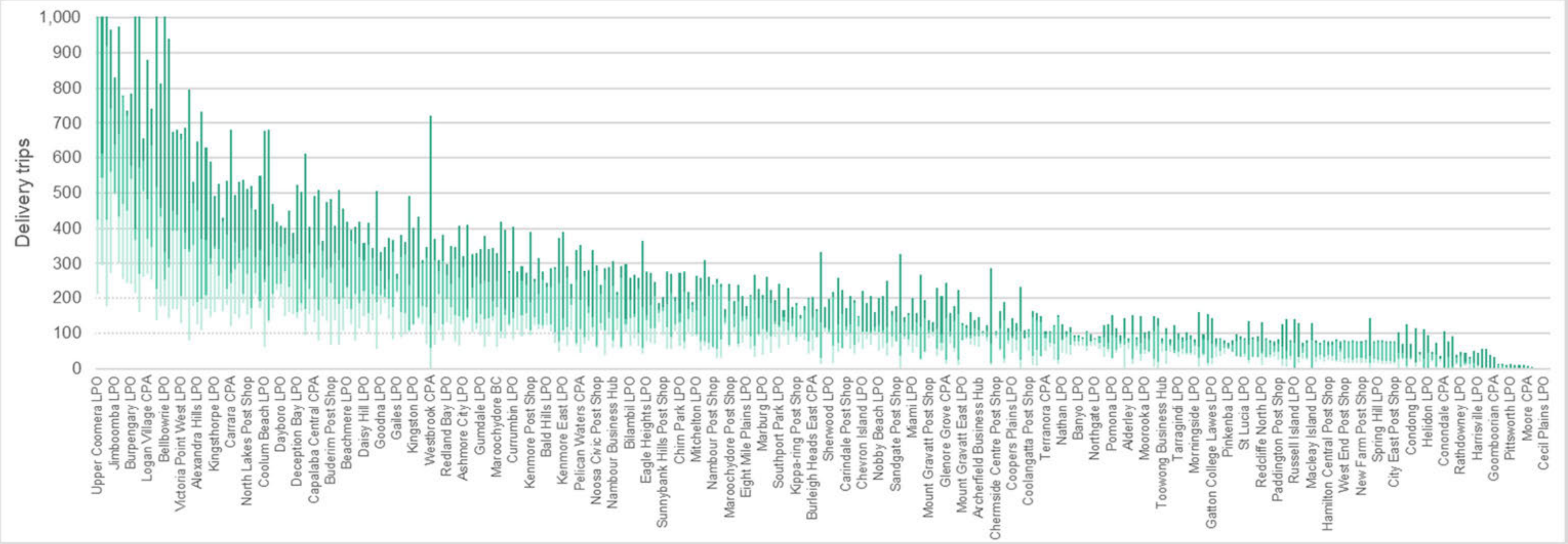


Figure A.2 Range of delivery trips per day per post office (proxy for local shops)

Table A.4 and Figure A.3 lists the assumptions and summarises the results of the four scenarios modelled. Scenarios 1 and 2 effectively allow customers to consider many more alternative restaurant options by increasing the distance served by drones.

While more customers can be served via the greater operating distance, the extra distance would increase noise impacts and risks.

While not included in the model, a variable operating distance would likely exist whereby customer catchments dictate the operating distance. In inner city locations for example, operating distances may be restricted, whereas more remote locations may benefit via the greater operating distances.

Table A.4 Function 2 general statistics

STATISTIC	SCEN. 1	SCEN. 2	SCEN. 3	SCEN. 4
Total trips made	67,000	130,000	106,000	158,000
Drone trips/day (per 1000 people)	6.2	12.1	9.8	14.6
Average distance (km)	10 km	9.5 km	3.4 km	3.3 km
Busiest port (two-way)	400	800	1,000	1,400
Drones/min (5hrs operations)	1.4	2.6	3.5	4.5
Total VKT (drones)	670,000	1.24M	360,000	520,000

Figure A.4 compares the spatial impacts of Scenario 1 and Scenario 4. This illustrates how the longer trip distance in Scenario 1 (up to 15 km) results in a more dispersed pattern of trips, despite the lower level of demand when compared to Scenario 4. The longer range for drone deliveries also allows rural areas to be served by drone deliveries.

The shorter service range of Scenario 4 (up to 5 km) results in a higher concentration of demand, especially for areas on the urban fringe with very few service centres within range.

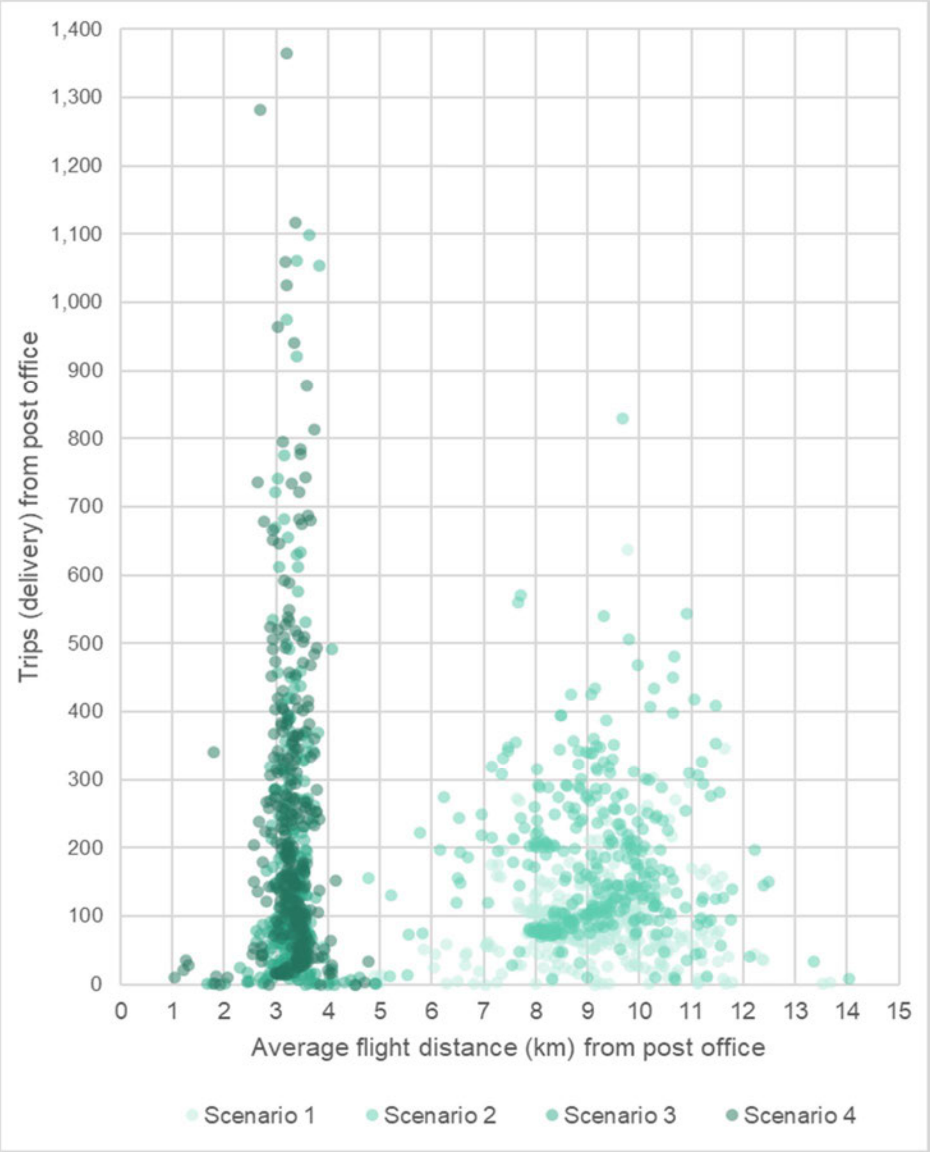


Figure A.3 Localised versus broad impacts caused by operating distance

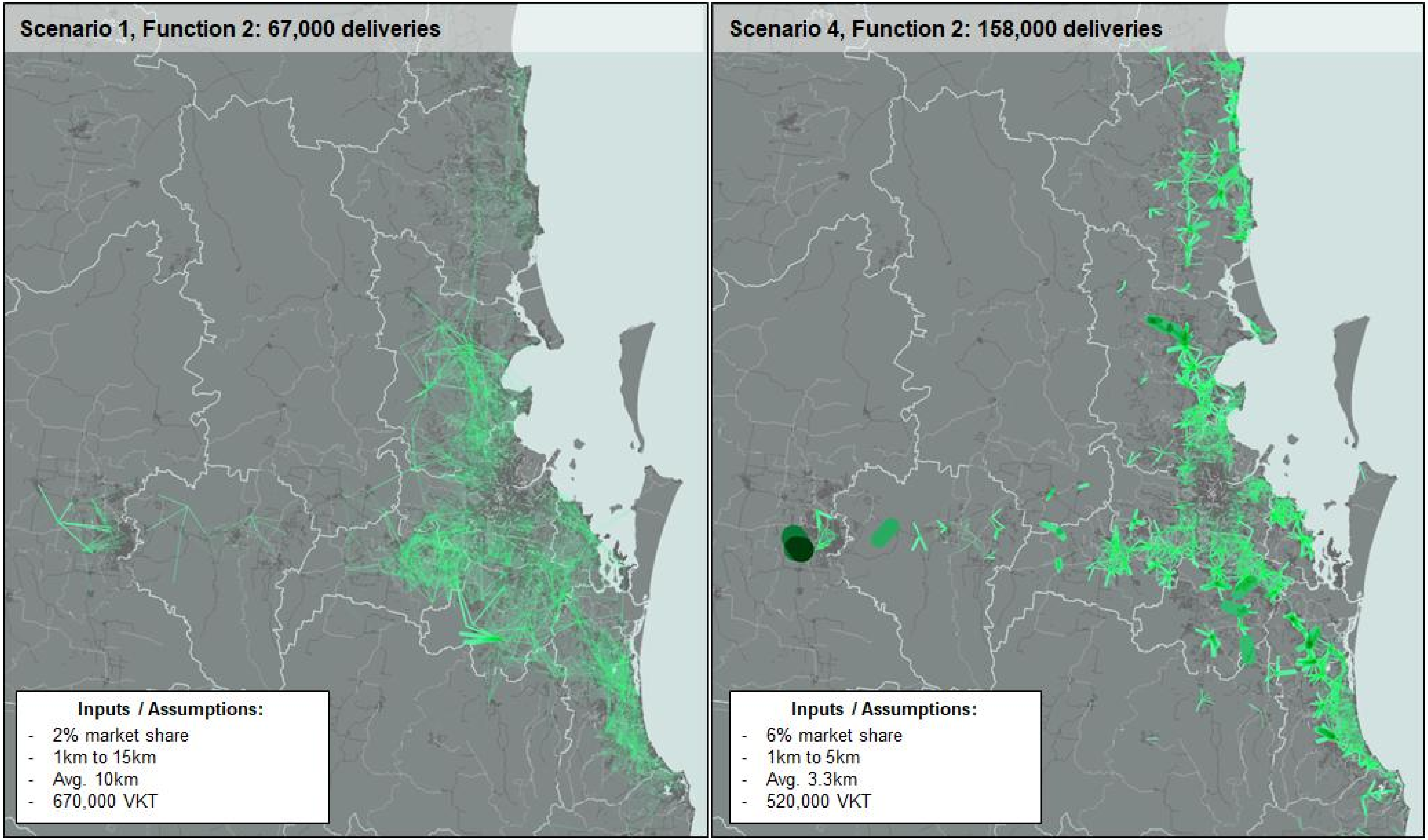


Figure A.4 Function 2: Scenario 1 and 4 spatial coverage of trip making

A3 DRONE DELIVERY OF PARCELS

The conceptual model's Functions 1, 3, 4, 5 and 6 represent the drone delivery of goods excluding takeaways. Function 1 relates to the short-distance courier service by drone and used 40% Australia Post delivery data to estimate potential. Functions 3 and 4 used ABS department store sales data was used to estimate potential demand. These are alternative operating models that vary the aggregation of goods distribution to customers. Function 5 was not modelled as no data is available on internal supply chain movements. Function 6 related to business-to-business trade with no data available to inform the analysis. Australia Post delivery data was used as a proxy.

Minimum distances vary by function and these were set at 1km, 5km and 10km. The conceptual model of the four scenarios varies the following factors: uptake, relative cost, number of objects per vehicle, and flight range.

Table A.5 summarises the assumptions and the overall demand across the four functions for each scenario.

Table A.5 Function 1, 3,4 and 6 general statistics

STATISTIC	SCEN. 1	SCEN. 2	SCEN. 3	SCEN. 4
Total trips made	41,000	71,000	121,000	115,000
Drone trips/day (per 1000 people)	3.8	6.6	11.2	10.7
Trips not made	6,000	14,000	13,000	22,000
Trips made %	88%	84%	90%	84%
Average distance (km)	24.5	23.2	33.7	27.6
Total VKT (drones)	1.0M	1.6M	4.1M	3.2M

Between the four scenarios, aside from the flight range, **the number of parcels per vehicle has the greatest impact/benefit** to customers and to SEQ residents.

For Function 4, for Scenario 2 and 4 it is assumed vehicles are carrying multiple objects per trip as a response to increasing demand and changes in supplier business models.

Figure A.5 below summarises these effects, highlighting how a doubling of payloads can effectively halve the number of trips and distance travelled per kilometre and enable drones to compete with existing logistics supply chains where large vehicles carry multiple products per vehicle. It is for this reason that delivery drones have the potential to efficiently support small business and market disruption.

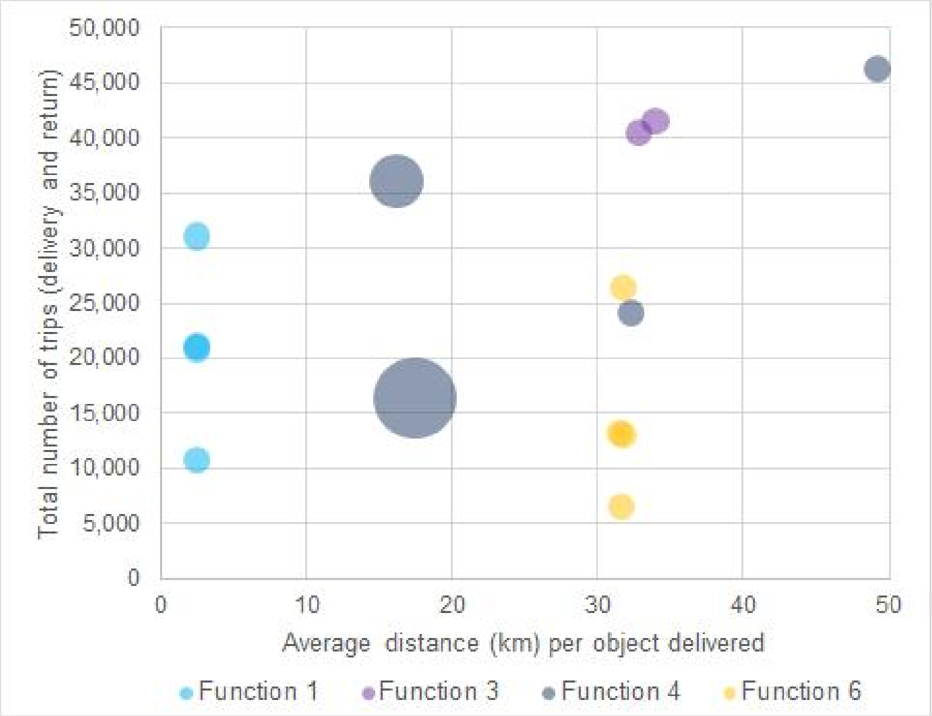
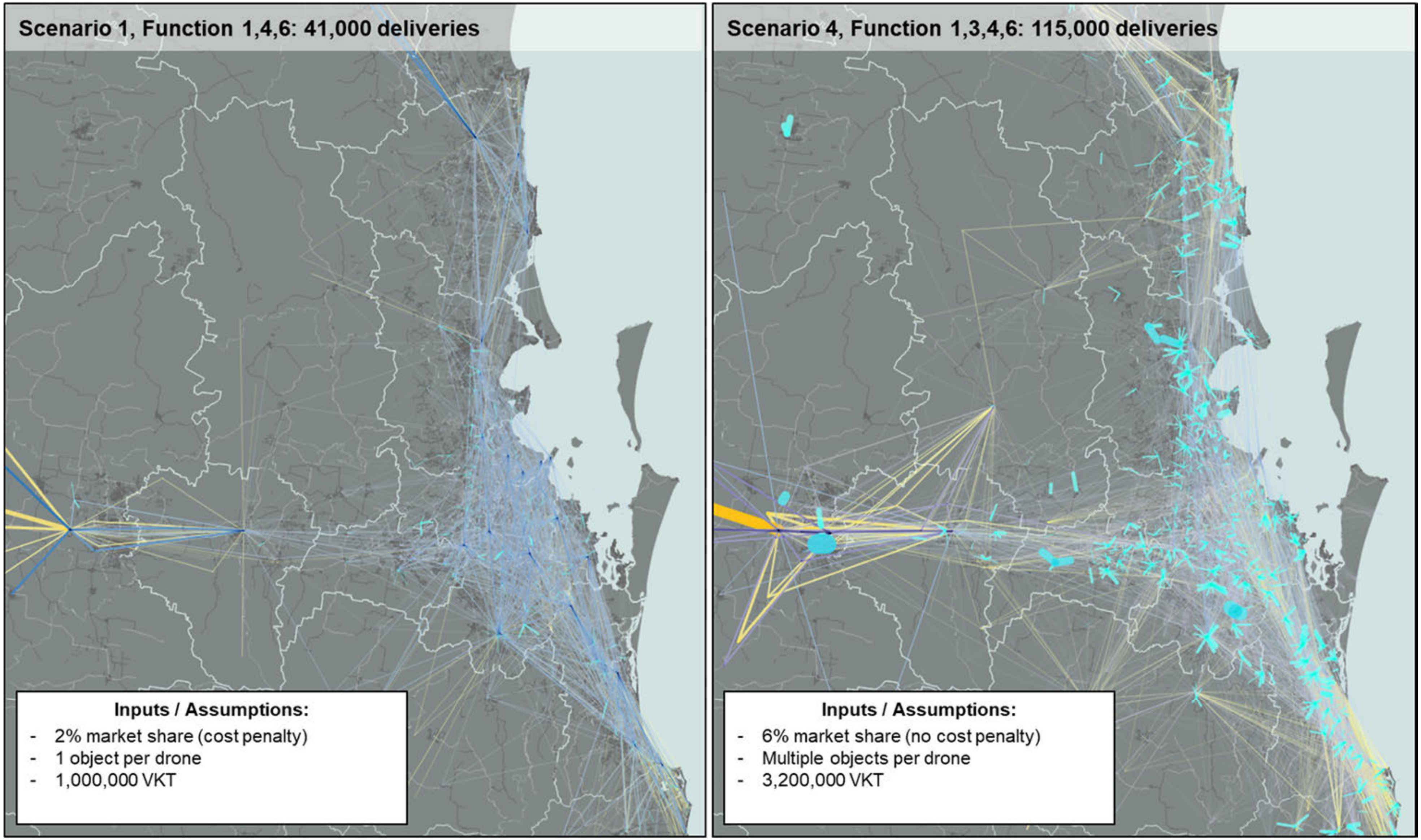


Figure A.5 Average distance per object efficiencies

Figure A.6 compares the spatial impacts of Scenario 1 and Scenario 4 and further highlights the conclusions presented in Table A.6.



Scenario 1, Function 1,4,6: 41,000 deliveries

Inputs / Assumptions:

- 2% market share (cost penalty)
- 1 object per drone
- 1,000,000 VKT

Scenario 4, Function 1,3,4,6: 115,000 deliveries

Inputs / Assumptions:

- 6% market share (no cost penalty)
- Multiple objects per drone
- 3,200,000 VKT

Figure A.6 Function 1,2,4 and 6: Scenario 1 and 4 spatial coverage of trip making

A4 DRONE MOVEMENT OF PEOPLE

The conceptual model's Functions 8, 9 and 10 represent movement of people by drone and include 'Air Metro', 'Air Taxi' and 'Personalised Air' respectively. In all cases, passenger-carrying drones were assumed to carry up to five passengers in line with current projections of passenger capacity for passenger drones (McKinsey & Company, 2018). Table A.6 summarises the overall demand across the three passenger drone functions where passenger drones operate. Scenario 1 assumes passenger drones do not operate in QLD.

The four scenarios vary the number of vertiports the relative attractiveness of passenger drones in each scenario. For passenger drones the number of vertiports makes the most difference to the passenger demand as it determines the time it takes to access the drone service. This therefore affects the travel time savings and reliability benefits passengers would achieve from drones if their origin or destination is outside the convenient first/last mile catchments of the vertiports.

Vertiport capacity was not a constraint modelled, but could potentially impact the efficient operation of passenger drones for busy vertiports such as the airport and central Brisbane.

Table A.6 Passenger drones' general statistics

STATISTIC	SCEN. 1	SCEN. 2	SCEN. 3	SCEN. 4
Total trips made	-	1,100	1,400	4,100
Drone trips/day (per 1000 people)	-	0.2	0.3	0.8
Average distance (km)	-	20.6	21.5	22.0
Busiest port (two-way trips/day)	-	550	470	1,100
Drones/min (12-hr operations)	-	0.8	0.6	1.6
Total drone kilometres (VKT)	-	23,000	74,000	91,000

Figure A.7 summarises Air Taxi users by comparing the drone travel time with base travel times of car trips they replace, including the first/last-mile travel time to access the vertiport. Points below the X=Y line are where drone users experience a travel-time benefit over car travel. The dot sizes highlight the volume of users.

The model assumed a maximum travel distance of 150 km, but results show that most of the demand is for shorter distance trips with the average trip distance between 20 km and 25 km. As shown in Figure A.7 the greatest travel time benefit would however be for users travelling for longer, whether due to long distances or slow travel speeds of ground transport.

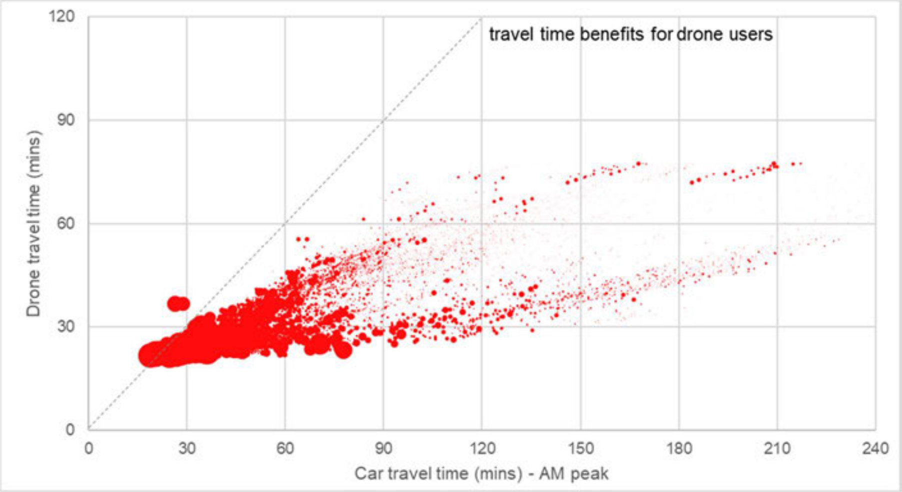


Figure A.7 Drone travel-time benefits versus car usage (Air Taxi)

Figure A.8 to Figure A.10 further present the potential travel-time and reliability benefits of using drone aerial transport vehicles. Figure A.7 demonstrates that these benefits will likely exist for users from outlying communities such as Toowoomba. It is expected that demand would be higher than that shown in the model.

The average drone speed (Figure A.9) will increase as distance increases due to the diminishing impact of the delay in the first-mile and last-mile on the overall journey. While the modelling uses a deterministic speed for drone operations, drone reliability is also anticipated to be superior to ground transport options.

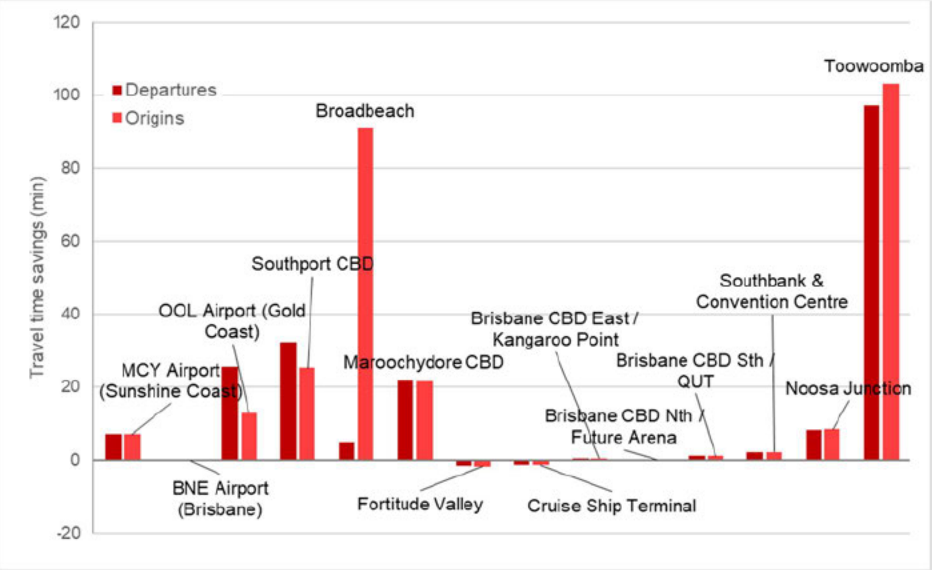


Figure A.8 Average travel-time benefits to/from vertiport (Air Metro)

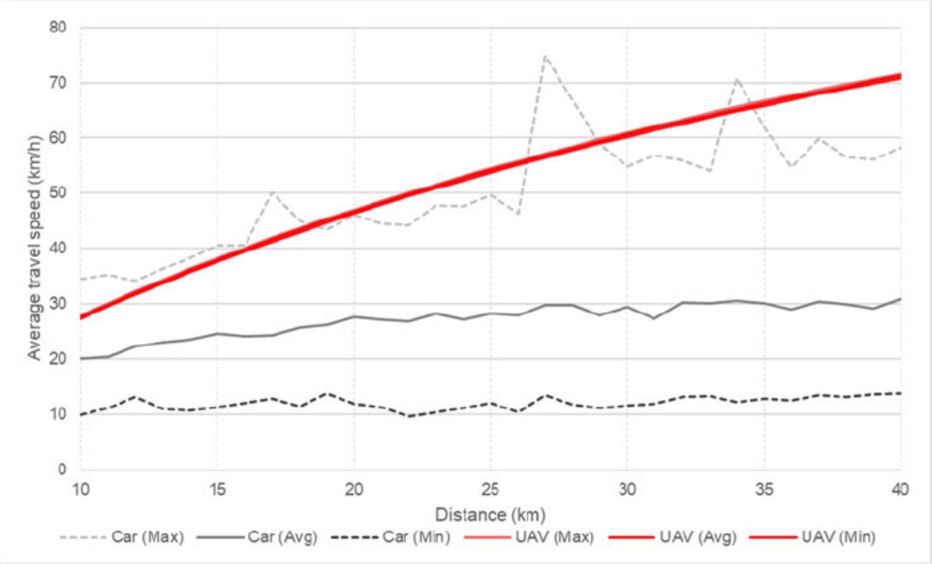


Figure A.9 Drone travel speed vs car travel speed by trip distance

Figure A.10 demonstrates the locations of travel-time benefits for 'Personalised Air' users. It clearly shows the existence of both use and travel-time benefits for travellers to/from Brisbane Airport. About 40% of the trips made by personalised air transport are between Brisbane Airport and other locations, with the total passenger use of drones being about 2%–3% of total air passengers forecast 20 years from now.

Figure A.11 summarises the total passenger drone trips for Scenario 4.

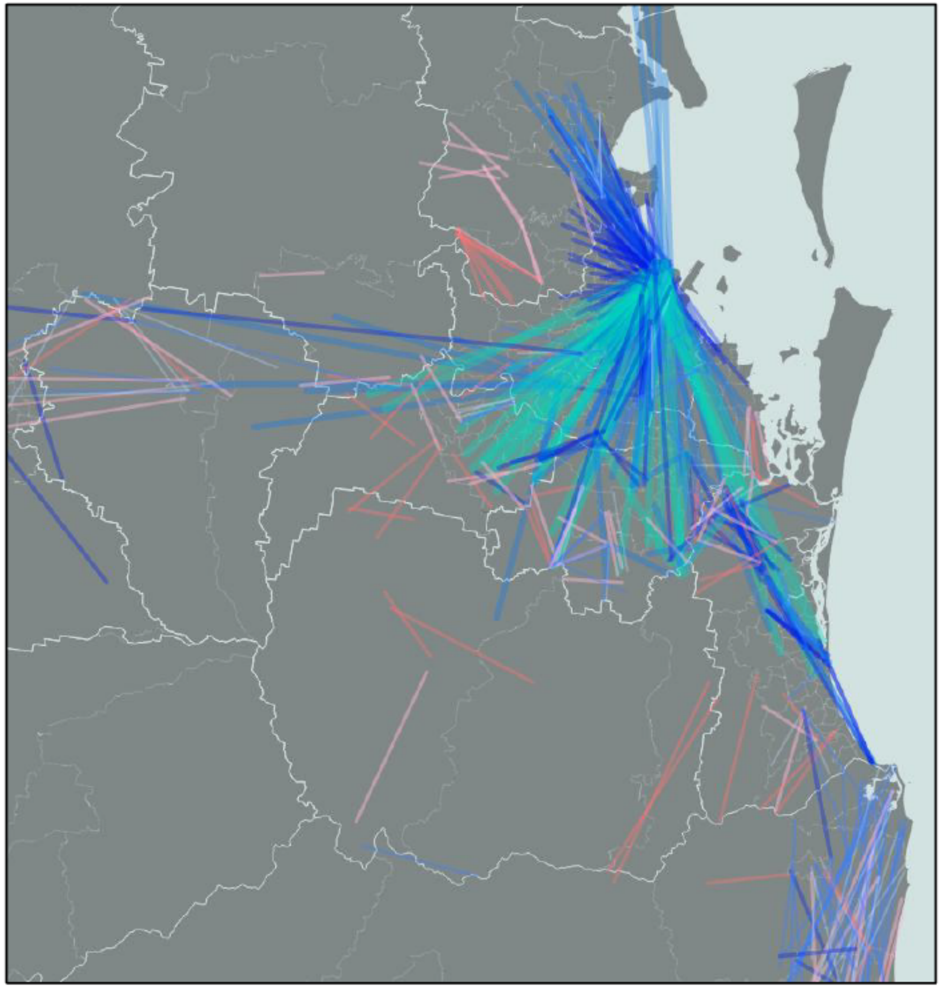


Figure A.10 Personalised air travel time benefits (spatial)

Figure A.11 Function 8,9 and 10: Scenario 4 spatial coverage of trip making

ABOUT US

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